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16. ABSTRACT

This study was undertaken to obtain information and data on irrigation tailwater and other components of irrigation return flows from two representative sites in the Central Valley of California. Extensive data on the quality and quantity of supply and drainage waters were collected for the 1975-77 period from the 664 km^2 Glenn-Coluse Irrigation District and the 113 km Colusa Basin Drain in the Sacramento Valley, and the 1620 km^2 Mendota-Crows Landing Return Flow Group in the west side of the San Joaquin Valley. This annual report presents the data and results obtained during the period of March 10, 1975 to March 9, 1976. Factors affecting tailwater production and quality are discussed in some detail. The specific field study sites in the San Joaquin Valley and the Sacramento Valley are described. Detailed data are provided in the appendices.

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IRRIGATION TAILWATER MANAGEMENT

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March 10, 1975 to March 9, 1976

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TABLE OF CONTENTS

Chapters — Page

I. INTRODUCTION AND PROJECT OBJECTIVES — 1

II. ACKNOWLEDGMENTS — 4

III. SUMMARY AND CONCLUSIONS — 5

IV. TAILWATER, A COMPONENT OF IRRIGATION RETURN FLOW — 9

V. FACTORS AFFECTING OR CONTRIBUTING TO TAILWATER PRODUCTION — 12

- A. Runoff as a Function of Irrigation Method and Related Physical Parameters — 12
- B. Runoff as Affected Indirectly by Other Factors — 17
- C. Analysis of Available Data and Information — 19
- D. Tailwater Control Practices and Reuse — 23

VI. FACTORS AFFECTING TAILWATER QUALITY — 30

- A. Tailwater Quality Constituents — 30
- B. Effect of Tailwater on Surface Water Quality — 41

VII. SAN JOAQUIN VALLEY FIELD STUDIES — 43

- A. Mendota-Crows Landing Return Flow Group — 43
- B. Broadview Water District — 58
- C. Panoche Water District — 65
- D. Los Banos Wildlife Area — 87

VIII. SACRAMENTO VALLEY FIELD STUDIES — 97

- A. Sacramento Valley Return Flow Group — 97
- B. Glenn-Colusa Irrigation District — 99
- C. Colusa Basin Drain — 119

IX. TOUR OF FIELD STUDY SITES — 127

X. THE ECONOMIC FEASIBILITY OF RECYCLING DRAINAGE WATER — 130

- A. Field Recycle Systems — 132
- B. A Farm Recycle System — 136
- C. The Effect of Alternative Irrigation Return-Flow Policies on Glenn-Colusa Irrigation District — 139

IX. APPENDICES — 145

I. INTRODUCTION AND PROJECT OBJECTIVES

In response to national demand for cleaner water, the Federal Water Pollution Control Act was amended by Public Law 92-500 in October, 1972. The objective of the Act is "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." The ultimate goal of PL 92-500 is to eliminate the discharge of pollutants into navigable waters by 1985, with an interim goal of achieving, "wherever possible," water quality that is "fishable and swimmable" by July 1, 1983. The Administrator of the U.S. Environmental Protection Agency (EPA) has been given the responsibility to implement and enforce this Act.

As part of PL92-500, research and development grants are being awarded. This group is one of the recipients investigating irrigation return flows. EPA Grant No. R 803603-01-1, Irrigation Tailwater Management, was initiated in March, 1975, for a two-year period. Supplemental financial support was also provided by the California State Water Resources Control Board under Standard State Agreement No. 4091400 for the period June, 1975, to March, 1976. A report on preliminary conclusions and recommendations was submitted to the California State Water Resources Control Board on February 27, 1976.

To control discharge of pollutants into navigable waters, EPA has a mandate under PL 92-500 to require the application of:

(a) "best practicable control technology currently available" (BPT or BPTCA) by July, 1977.

(b) "best available control technology economically achievable" (BAT or BATEA) by July, 1983.

(c) "elimination of discharge of pollutants" (EOD) by 1985.

The ultimate goal of EOD has been recently interpreted by the Staff of the National Commission on Water Quality as "the elimination of the discharge of pollutants shall apply to removal of those constituents which are added during use of the water. The resultant discharge must be of equal or lower concentration than that of the original supply." Moreover, EOD applies only to point-source discharge of pollutants, and not to nonpoint sources.

It should be pointed out that PL 92-500 does not explicitly identify the control technology desired, but only the goals to be achieved. However, in the implementation of this Act, uniform waste discharge requirements are being promulgated for municipal sewage effluents and most industrial wastewater discharges. For example, secondary treatment of municipal sewage effluents meets the 1977 BPT goal. Similar waste discharge requirement/control technology has not been spelled out for irrigation return flows. Yet, what is now being enforced is the National Pollutant Discharge Elimination System (NPDES) permit program, which does apply to surface irrigation return flows discharged from an identifiable source. The NPDES permit system, administered by the State Water Resources Control Board and its Regional Boards in California, initially involves a self-monitoring program in which permittees are required, among others, to report the flow, electrical conductivity, and suspended solids of supply and discharge waters.

Irrigation tailwater, in some quarters, is considered to be the easiest component to control of the point-source surface irrigation return flow. If tailwater is controlled and/or reused, irrigation application efficiency would be improved, water and energy would be conserved, and, at the same time, water pollutional problems would be substantially reduced. So, tailwater management appears to be a logical and practical control technology. But the question is, is it really? This is the focus of our investigation. It is our contention that before a blanket recommendation on irrigation tailwater management is made at the on-farm level, there is a need to investigate more fully such a management recommendation.

Irrigation tailwater control and reuse appear to be a deceptively simple management practice, but in fact are a very complex practice because of the many factors contributing to and/or affecting tailwater and its quality. To help us understand this complex problem, field studies are being conducted in two of California's first and largest NPDES permittees: the Mendota-Crows Landing Return Flow Group in the San Joaquin Valley and the Sacramento Valley Water Quality Committee in the Sacramento Valley. These field studies are intended to provide us with exposure to "real-world" problems, and case study information and data to develop guidelines for the management of tailwater. Concurrently, economic studies are also being carried out.

The objectives of this project are (1) to identify and evaluate factors contributing to or affecting irrigation tailwater production and its quality, (2) to carry out field studies in selected areas in the Sacramento and San Joaquin River Basins, (3) to determine the least-cost combination of agricultural production and labor, capital, irrigation water, and tailwater management and reuse, and (4) to integrate scientific, engineering, and economic appraisals for the recommendation of guidelines for best practicable technology for irrigation tailwater management.

In the first year of our project, our activities were focused mainly on project objective (2), the selection of field study sites and the initiation of sampling/monitoring programs. Results from the 1975 irrigation season are reported herein. Objective (1) was also pursued and our findings are given in this report. It should also be mentioned that another ongoing EPA project is developing a literature review on irrigation return flows and quality. In addition, the methodology and modeling for economic studies, objective (3), are contained herein. A preliminary assessment of objective (4) has been made, but economic evaluations are yet to be incorporated. The results of this preliminary assessment have been reported to the California State Water Resources Control Board.

II. ACKNOWLEDGMENTS

We hereby acknowledge the generous contributions and support given to this investigation by field study site cooperators and interested collaborators. We have received expert advice and suggestions regarding the selection of possible field study sites and monitoring stations. We have also received ready access to records, and assistance in the collection of water samples and maintenance of monitoring stations as well as in the design, fabrication, and installation of certain water-flow measuring stations.

We are indebted to the following cooperators:

Mendota-Crows Landing Return Flow Group (C. W. Bates, T. McCullough)

Central California Irrigation District (W. Raznoff, R. Pfitzer, S. Cook)

Panoche Water District (R. Ram)

Broadview Water District (S. Durrenberger)

Los Banos Wildlife Area (J. Cawthon, D. Connelly)

Enrico Brothers Farm

R & N Farms

Sacramento Valley Water Quality Committee (D. E. Kienlen, A. E. McCollam)

Glenn-Colusa Irrigation District (R. Clark, D. Haapala)

Rice Growers (R. Roberts, H. Knight, H. Plank, M. Garcia)

We are also indebted to numerous collaborators, to mention a few:

Central Valley Regional Water Quality Control Board (R. E. Merrill, W. Tyler, K. Van De Pol)

Soil Conservation Service (R. E. Hulbert, R. W. Robb)

San Joaquin Valley Interagency Drainage Program (W. R. Johnston)

Department of Water Resources (R. F. Clawson, V. B. McIntyre, J. L. Welsh)

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III. SUMMARY AND CONCLUSIONS

This report covers the first year of a two-year investigation. The first year's activities were focused primarily on the collection of field data and information for the 1975 irrigation season in selected study areas in the Central Valley of California, the development of economic models, and preliminary assessment of factors contributing to or affecting tailwater production and quality.

Our field studies are being carried out in two of California's first NPDES permits issued for the discharge of irrigation return flows. The San Joaquin Valley study area is located in the 400,000-acre Mendota-Crows Landing Return Flow Group on the west side of the Valley in Fresno, Merced, and Stanislaus Counties. This Group, consisting of 17 entities, utilizes imported water from the Sacramento River Basin via the Delta-Mendota Canal and the California Aqueduct, and discharges their return flows in the middle reaches of the San Joaquin River. In addition to the two supply and three discharge NPDES monitoring stations for this Group, this project has seven internal stations located upstream from the discharge points in the drainage network. Three entities in this Group are intensively being studied; namely, Broadview Water District, a 10,000-acre district which captures and reuses all of their surface irrigation return flows, Panoche Water District, a 44,000-acre district which discharges most of their drain water into grassland and wildlife habitats where extensive reuse of return flows occur, and the Los Banos Wildlife Area, a 3,200-acre refuge that uses irrigation and other return flows and is devoted to such recreational activities as hunting, fishing, nature studies, and camping and picnicking.

The second field study area is located in the Sacramento Valley. The Sacramento Valley Water Quality Committee has received an NPDES permit to discharge irrigation return flows into the Sacramento and Feather Rivers through thirteen major drains. This return flow group is comprised of more than 47 co-signers and represents about one million acres of irrigated lands extending from the City of Sacramento to Hamilton City. Our project activities are focused on the 164,000-acre Glenn-Colusa Irrigation District, a typical district on the west side of the Valley with flooded rice culture as a major crop. This district obtains its supply water by diversions from the Sacramento River and Stony Creek, and discharges its return flow into the Colusa Basin Drain. Glenn-Colusa Irrigation District captures drain water by gravity and pumps approximately equal to 27% of the diverted water. The Colusa Basin Drain is a 70-mile canal that conveys return flows during the irrigation season and flood runoffs during the nonirrigation season. The flow in this drain is discharged into the Sacramento River upstream of Knights Landing through its outfall gates as well as into the Yolo Bypass through the Knights Landing Ridge Cut.

The technical data and information are reported in their entirety in Chapters VII and VIII, and the Appendices. The importance of our field experience cannot be overly stressed. It has contributed significantly to Chapters V and VI which contain our appraisal on tailwater production and quality, and to Chapter X, economic studies.

Instead of summarizing the technical and other details, we choose to point out some of our major findings as follows:

- Irrigation tailwater is produced under a variety of conditions. It is exceedingly difficult to eliminate runoff from surface irrigation methods. Tailwater is prominent in flooded rice culture and in certain other cultural practices, such as during seed germination in furrow beds.
- In areas where water is scarce or costly, tailwater is seldom produced or is reused at the site of production. It is not, however, unusual

to find from 10 to 30% of the diverted water being reused, even in the areas where the supply of water is plentiful and inexpensive.

* Tailwater is seldom collected and/or disposed of in a drain separate from other surface irrigation return flow components. Where this was the case, we monitored the surface return flows.

* Runoffs discharged from irrigated fields may not always reach the receiving water body due to capture and reuse, either at the site of production or at downstream locations.

* The quantity and quality of surface irrigation return flows are highly variable, reflecting local differences in the hydrologic and geologic conditions, soil properties, cropping patterns, cultural practices, supply water, and the extent of reuse.

* In many instances, it is difficult to differentiate the sources of pollutants between natural and man-induced processes. In addition, it is often difficult to differentiate the source of discharge waters between rain-fed and applied irrigation waters.

* In many sites, it is difficult to monitor water flow due to the lack of suitable structures and the prohibitive costs of setting up water flow measuring stations for this project. Furthermore, in some sites, it is difficult to estimate water flow because the flow of water may reverse its direction for a variety of reasons.

* Although the reuse of irrigation return flows is a desireable goal, the quality of irrigation return flow may at times be a major constraint. For instance, the boron and salinity levels may be exceedingly high. In spite of these hazards, such degraded waters are being utilized after blending with waters of higher quality.

* Tailwater control may be viewed as promoting greater water-use efficiency. This usually results in a higher concentration, but a smaller mass

emission of pollutants. However, such a practice may lead to other potential problems, such as a diminished summer flow in streams, a diminished supply of water for subsequent or downstream water users, and perhaps an inadequate stream flow to repel sea water intrusion in the Sacramento-San Joaquin Delta.

* Alternative tailwater management practices have been identified. A few of them may be applicable, while others are not. Due to the site variability of receiving waters, and of tailwater production and quality, it is difficult to recommend any single universally applicable tailwater control technology. The effect(s) of tailwater discharge into surface waters may be either beneficial, detrimental, or both, depending on the quality constituents of interest and flow regime. A practice that is effective in one location may not be as effective in another.

IV. TAILWATER, A COMPONENT OF IRRIGATION RETURN FLOW

Figure IV-1 gives a schematic representation of the fate of water diverted by irrigated agriculture. Irrigation return flow is defined as that portion of this diverted water not consumptively lost to the atmosphere which returns back to either surface or subsurface bodies of water. Surface runoff, commonly referred to as tailwater, is one of the components of irrigation return flow.

Recently, pollutants have been categorized into point and nonpoint sources. Presumably this categorization was made to assist in water quality control, i.e., point sources of pollutants are more amenable to control than nonpoint sources. However, by definition, point discharges of pollutants are those pollutants collected in a conduit, drain canal or other man-made structures or natural land forms (such as sloughs), and discharged as a discrete, discernible outfall into a water body. In contrast, nonpoint discharges of pollutants are those uncollected pollutants, diffuse in origin, with no discrete outfall into a body of water. It should be pointed out that the above definitions relate to "collected or uncollected discharges," and not to "point or nonpoint origins" of pollutants. For example, leaching (seepage) from irrigated lands is considered a nonpoint source, but if it is collected by natural or artificial means and discharged from a discernible outlet, it is then regarded as a point discharge.

In this context, the point-source surface irrigation return flow may be comprised of operational spills (bypass water) from water distribution systems, irrigation runoff (tailwater), and collected subsurface drainage water from tile drains, open ditches, and drainage wells. Note that some of these components may have been initially diffuse in origin, but have been collected and emitted as a point discharge.

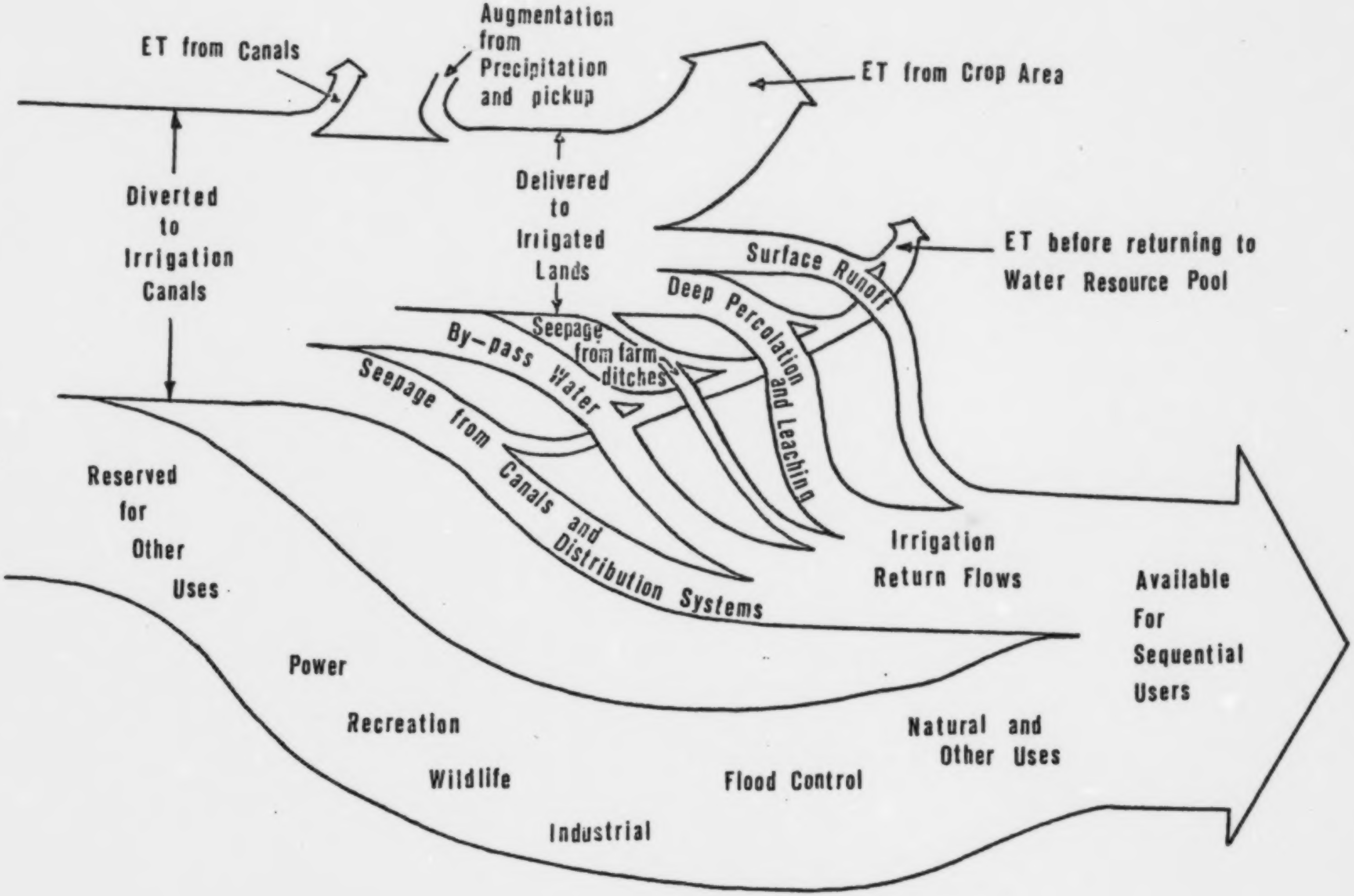
ET from Canals
Augmentation from Precipitation and pickup
ET from Crop Area
Diverted to Irrigation Canals
Delivered to Irrigated Lands
ET before returning to Water Resource Pool
Surface Runoff
Deep Percolation and Leaching
Seepage from farm ditches
By-pass Water
Seepage from Canals and Distribution Systems
Reserved for Other Uses
Irrigation Return Flows
Available For Sequential Users
Power
Recreation
Wildlife
Industrial
Flood Control
Natural and Other Uses

FIG. IV–1 : DIAGRAM ILLUSTRATING THE DISPOSITION OF WATER DIVERTED FOR IRRIGATION PURPOSES

With few exceptions, irrigation tailwater is not collected in a drain, sump, or conduit separate from other surface irrigation return flow components. Thus, it is often difficult to measure the quantity and quality of tailwater, unless flow measuring-water sampling stations are established between the irrigated field and its drainage system. Moreover, other than in flooded rice cultures, tailwater is produced intermittently, coinciding with irrigation schedules. In a later section, it will be pointed out that the quality of surface runoff differs markedly from that of collected subsurface drainage. This may indirectly give an estimate of the relative proportions of these two components.

V. FACTORS AFFECTING OR CONTRIBUTING TO TAILWATER PRODUCTION

A. Runoff as a Function of Irrigation Method and Related Physical Parameters.

A detailed discussion is presented of the adaptability and likely performance of irrigation methods in relation to various cultural practices, soil properties, slope, etc.

1. Surface Irrigation. The parameters of major interest in surface irrigation methods are: (1) rate of advance, (2) rate of recession, (3) infiltration rate, (4) boundary geometry, (5) roughness, and (6) inflow rate (stream size). Other major controlling factors which could have been listed are susceptibility of the soil to erosion, and the changing demands (seasonally and annually) of the amount of water needed for each irrigation. For many situations, one or more of the above factors produce restraints on farmers which make it very difficult to achieve high irrigation efficiencies under some methods of surface irrigation (or even sprinkler irrigation).

A brief review of methods of surface irrigation follows to point out the interrelationships of some of the above factors within and between the various approaches to surface irrigation. Surface methods are based on distinct differences in desired relationships, e.g., between rate of advance, rate of recession, time when water is turned off or cut back, size of stream, and other factors. Even if infiltration, roughness, susceptibility to erosion and climate were not highly variable, there are basic differences in the various methods, and different procedures are required for irrigators to achieve high efficiency. An appropriate choice of method is, of course, the first important management decision related to efficient irrigation. Certain methods are precluded from use under various combinations of conditions, if efficient irrigation is desired.

The material presented is based largely on Chapter 4, Section 15, SCS Engineering Handbook, and University of California bulletins. Some of the more important factors concerned with adaptability and limitations under various combinations of conditions are considered in the following:

a. Level-Border Irrigation -- For flat areas, where level borders are appropriate, runoff is not likely in most cases. However appropriate advance-recession relationships for this method suggest that water should reach the end of the run within 60 percent (or less) of the time required to infilter the desired net application, Fn, into the soil. Otherwise deep percolation losses > 20% of the applied water will result. With level borders then, water is run for some time after the stream reaches the end of the border, and until a desired gross depth of application to the border is achieved (Fg = 100 Fn/Design Efficiency in %).

b. Graded-Border Irrigation -- High efficiency graded-border irrigation requires even more careful attention or adjustment of controllable factors (mainly stream size and length of border). A near balance of advance and recession is needed, but difficult to achieve. In general, the stream size (a nonerosive one, but deep enough to give good lateral spreading) must be such that the desired gross depth of water is applied (Fg) to the strip in a time equal to, or slightly less, than the time needed for the soil at the head of the border to absorb the net amount (Fn) required. Hence, a proper balance of several parameters is needed, i.e., Fn, time required for Fn to infiltrate, stream size, stream depth, roughness of surface, slope and length of border. Too large a stream size results in an inadequate irrigation at the upper end of the strip, or in excessive runoff. If the stream is too small, the lower end of the strip is inadequately irrigated, and the upper end has excessive deep percolation. Poor lateral spreading may also result. Note that in contrast to level borders, the stream should be turned off well before water reaches the end of the border. In graded borders, the use of end blocks can greatly reduce runoff, but may result in much deep percolation. Also, they become impractical on steeper graded borders and for crops which can withstand only a few hours of submergence (e.g., alfalfa under hot conditions).

Graded-border irrigation can be used on most soils. Problem cases are very low intake soils where, if water is left on long enough to apply Fn at the head of the border, excessive runoff occurs. Coarse sandy soils are difficult to handle with other than very short borders. Graded-border irrigation is best suited to slopes of $\leq$ 0.5 percent.

c. Guide-Border Irrigation -- This SCS classification is a special case of border irrigation and should be of particular interest in a report concerning tailwater management. It is this method which basically involves a combination of conditions which preclude the chance of a balanced advance recession situation, and in which there is no way to provide for a desired infiltration of water, Fn, at the head end of the borders without adding a gross amount, Fg, which is far too great for a reasonable irrigation efficiency. Guide-border irrigation generally involves steeper grades, where large stream sizes are required to achieve a depth of flow great enough to give an adequate lateral spread in the border, and good coverage despite the uneveness of grade (laterally). These larger stream sizes (as compared to graded borders) result in a significant amount of tailwater.

The SCS suggests that very inefficient irrigation will result with this method unless return flow systems are employed, or unless runoff is redirected to lower elevation fields. It should be pointed out that many border irrigation layouts, even on slopes < 0.5 percent and seemingly fitting a graded-border irrigation classification, really should be recognized as fitting the guide-border case. This is true for soils down to slopes as low as 0.1 percent when, due to very low intake rates, a long time is required for infiltration of a desired Fn. With an adequate stream size for good spreading, much runoff will occur, even with these borders of rather low slope. This problem can be overcome to some extent by using lighter and more frequent irrigations, or by the use of return flow systems.

In terms of timing of water on and off, guide-border irrigation is similar to that for level-borders than for graded borders. For graded borders, water is turned off before it reaches the end of the strip, whereas for the first two, a desirable distribution depends upon getting the water through and then letting the stream run for quite some time thereafter.

d. Contour Furrow — Contour-furrow irrigation has characteristics similar to level borders, except for the limitation in effective depth of application, which is represented by a nearly full furrow. In level borders, the levees are high enough so that an effective depth of up to 6-8 inches of water can be stored within the border. With level furrows, however, only 1-2 inches of storage may be involved. Hence, for heavier irrigations, careful control of stream size once the water reaches the end of the furrow, is necessary to avoid water breaking over the sides, and to limit runoff. A balance of stream size and furrow length will allow the water to reach the end of the furrow in 1/4 to 1/3 of the time needed to infilter the desired net application, Fn.

e. Graded Furrows -- Except for furrows laid out on almost flat slopes, the rate of recession once water is turned off is rapid enough so that it is not necessary to consider the time involved in recession. This is partially because considerably longer intake opportunity times are needed in furrow irrigation, as compared to border irrigation, to infilter a given Fn. The major procedural difference between graded furrows and graded borders is the desirability in the latter case getting water to the end of the furrow in 1/4 to 1/3 of the time needed for Fn to infilter. Hence, the stream is continued for a long period after runoff commences. Unless the stream size is reduced (cut back) runoff can easily represent a 30 to 40% loss. To avoid runoff, most farmers tend to use smaller streams, taking longer to get the water through and turning off the water soon after it reaches the end. Although this produces minimal runoff, the distribution of infiltered water is very poor, and much deep percolation in upper portions of the furrow may occur. More frequent irrigation may be required to meet optimal growth conditions in the lower portions of the furrow. It should be noted that this may apply to mid-run portions for furrows laid out on flatter slopes, if the furrows are blocked on the end or if there is no place for tailwater to drain away from the lower end of the field. This could result in deep percolation at both the upper and lower ends.

Graded furrows, unless located on flatter slopes, also present a serious erosion hazard, with resultant high turbidity levels in tailwater.

This is especially true for early irrigations following planting and cultivations. This problem is much more serious in furrow irrigation than in border irrigation.

f. Corrugations -- The principles here are similar to those for graded furrows, except for the possibility of even more serious erosion and high turbidity tailwater. Corrugations are used on steeper slopes where the much larger furrows are impractical. Runs must generally be considerably shorter than for graded furrows, and stream sizes are usually limited to 10 gpm or less.

2. Sprinkler Irrigation. In general, tailwater is not considered to be a problem in sprinkler irrigation. If the system is properly designed to apply water at an application rate less than the minimum intake rate of the soil (near the end of the time of application), runoff should not occur. The traveling systems (Big Gun or Center Pivots) are inherently high application rate systems, and where employed on some medium or fine textured soils, a very significant runoff can occur and, if erosion is serious, this runoff may contain high loadings of sediments.

3. Trickle or Drip Irrigation. Although runoff may occur locally (around drippers) a properly designed system should seldom, if ever, produce any runoff from an entire field. On rolling hills or steep hillsides, adequate design involves the use of pressure regulators on sub-mains, with laterals running on the contour. Otherwise, over-irrigation and resultant deep percolation will occur on lower elevation areas (presuming an adequate water supply at higher elevations).

B. Runoff as Affected Indirectly by Other Factors (e.g., supply, cost, labor, etc.).

A detailed analysis of factors such as cost, labor supply, etc., is not the purpose of this section, but our purpose is to point out the possible significance of such factors as they affect tailwater production. In the absence of specific regulatory controls imposed upon the irrigation farmer, the factors discussed in V-A may be of little significance. Farmers have developed irrigation techniques largely on the basis of what will get the job done at a reasonable cost, provide high yields, and avoid the development of easily discernible local problems.

The technology (other than the rather simple aspects) is of little interest when water costs (including local transfer costs) are low. Initiation of a higher level of sophistication in irrigation management, to save 15-30% of total applied water, is unlikely when (1) availability of water is not a question; (2) cost of delivered water to the farm, or of pumped water from wells, is low; (3) labor capable of carrying out such changes is scarce and costly; (4) physical systems involved in initiating better control, e.g., tailwater return systems, have a significantly higher annual cost than that of the water saved; (5) good evidence exists that present techniques are providing top yields; (6) there are no immediate evidences of problems due to serious erosion, rising water tables, etc.; and (7) the individual farmer has a convenient way of disposing of any amount of tailwater without apparent damage to himself or to his neighbors.

Unless the change to sprinkler irrigation (or trickle) from surface methods can be shown to have distinct advantages, only a significant change in one or more of the above factors, or the outright imposing of controls, is likely to bring about a change in management practices. This is understandable if one carefully considers the rather complex interrelationships covered earlier. This is especially true in light of the compounding complexity imposed upon the farmer by the frequently dramatic variation of evapotranspiration demand, as well as the variable nature of several of the more important physical parameters involved in surface irrigation, e.g., infiltration rates varying by a factor of 2 to 5 with different crops on the same soils, or erosion (with a given stream size) varying by an order of magnitude between pre- and post-cultivation irrigations.

C. Analysis of Available Data and Information.

The largest single water user in California is irrigated agriculture. Present estimates indicate agricultural water use at 85% of the developed water in the State. There have been numerous reports on applied water, evapotranspiration, irrigation efficiency, etc. Rather than reviewing all of these reports, the more recent regional-wide or basin-wide studies in California are mentioned.

Bulletin No. 113-3, Vegetative Water Use in California (April, 1975) reports the results of over a decade of comprehensive state-wide investigations by the Department of Water Resources (DWR), and by the U.S. Department of Agriculture, Agricultural Research Service, and the University of California under contracts and agreements with DWR. The estimated evapotranspiration (ET) data in this report for the various crops in various regions of the State are not based on some ET prediction formula, but on very detailed field measurement programs. For extrapolation to regions some distance away from the actual ET study sites, the relationships developed at the study sites between ET and pan evaporation (Class A) are employed along with evaporation data from pans located in very carefully controlled irrigated pasture environments at many sites in the State.

A second report has recently been submitted to the State Water Resources Control Board by Dr. Ian Stewart, University of California, on "Irrigation in California." It contains the results of a comprehensive survey on irrigation locations, irrigated acreages (9.1 million acres), crop types, applied water, and irrigation methods for 1972. More than 75% of the irrigated crop acreage and irrigation water used is in the Central Valley.

In the Central Valley, 70% of the irrigated acreage is in field crops (irrigated pasture, alfalfa, cotton, small grains and miscellaneous hay, rice, sugar beets, corn, and grain sorghum). Field crops are primarily irrigated by surface methods (89%), mainly borders and furrows. However, significant acreages of cotton, alfalfa, and irrigated pasture are also sprinkled. Trees and vines occupy 22% of the irrigated acreage; the major commodities being grapes, almonds, walnuts, citrus and avocadoes, peaches and nectarines, and prunes. Most of the trees and vines are surface irrigated, but about 25% of this acreage is sprinkled, with about 1% in drip irrigation. Grapes and citrus are commonly irrigated by furrows, while other types of orchard are commonly irrigated by borders. Solid set sprinklers for frost protection and summer cooling, and drip irrigation, are being used increasingly. Vegetable crops occupy about 8% of the irrigated acreage in the Central Valley. Tomatoes, beans, and potatoes are the major crop type and are usually furrow irrigated and/or sprinkled.

Tables V-1 and V-2 summarize Stewart's data, along with a comparison of applied water and efficiency from the DWR report. The implied efficiencies give a significantly higher efficiency for many crops than is normally quoted, considering the very high percentage of land which is irrigated by surface methods. For the most part, these values do not reflect the increased overall project efficiency which would come from the reuse of irrigation return flows. For example, the recent DWR study on irrigation efficiency on the west side of Sacramento Valley points out that even though individual farm irrigation efficiencies may be low, the downstream reuse of return flows results in a basin irrigation season efficiency of about 70% for the 1960-70 period. Irrigation efficiency is also reported to be increasing with time due to greater reuse and by slight increases in irrigated acreage without increases in water supply.

Table V-1. Sacramento Valley Irrigation Efficiency

Crop	Estimated Growing Season ET[1] af/a	ET of Applied Water[1 2] af/a	Applied Water af/a SWRCB[3]	DWR[1]	Efficiency in %[4] SWRCB[3]	DWR[1]
Alfalfa	3.5	2.6	3.8	3.8	68	68
Barley	1.0	0.0	—	1.0	—	—
Beans (dry)	1.4	1.1	2.0	—1.9[5]	55	—58[5]
Corn (field)	2.0	1.8	2.5	—1.9[5]	72	—95[5]
Deciduous Orchard	3.2	2.2	2.9	3.0	76	73
Almonds	2.4	1.6	2.9	—	55	—
Grain Sorghum	1.8	1.4	2.0	—1.9[5]	70	—74[5]
Pasture	3.6	2.9	5.1	5.1	57	57
Potatoes	1.6	—	—	—	—	—
Subtropical Orchard	2.6	1.6	2.8	—	57	—
Sugar Beets	2.5	1.7	3.0	3.1	57	55
Tomatoes	2.3	1.7	2.6	2.4	65	71
Vineyard	2.2	1.7	3.0	3.0	57	57
Rice	3.5	3.3	8.2	9.0	40	37

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[1] State of California, Department of Water Resources, Vegetative Water Use in California, 1974 Bulletin No. 113-3, April 1975.

[2] Based on a rainfall zone with an average annual precipitation of 16-18 inches.

[3] Stewart, J. Ian, Irrigation in California. Report to the State Water Resources Control Board. June 1975.

[4] $$\text{Efficiency} = \frac{\text{ET of Applied Water}}{\text{Applied Water}} \times 100$$

[5] This figure was developed for miscellaneous field crops, not the individual crop under which it is listed.

Table V-2. San Joaquin Valley Irrigation Efficiency

Crop	Estimated Growing Season ET[1] af/a	ET of Applied Water[1] [2] af/a	Applied Water af/a SWRCB[3]	Applied Water af/a DWR[1]	Efficiency in %[4] SWRCB[3]	Efficiency in %[4] DWR[1]
Alfalfa (hay)	3.5	3.1	5.1	4.7	61	66
Barley	1.4	0.9	—	1.4	—	64
Beans (dry)	1.4	1.3	2.5	2.6	52	50
Cantalopes	1.1	1.0	—	3.1	—	32
Corn (field)	2.0	2.0	3.2	3.2	63	63
Cotton	2.6	2.5	3.8	3.7	66	68
Deciduous Orchard	3.2	2.8	4.2	3.5	67	80
Almonds	2.2	1.9	3.3	—	58	—
Grain Sorghum	1.8	1.7	2.5	2.5	68	68
Pasture (improved)	3.7	3.3	5.5	6.0	60	55
Potatoes	1.6	1.2	3.7	—	32	—
Rice	3.8	3.5	6.7	6.7	52	52
Subtropical Orchard	2.6	1.9	2.3	—	83	—
Sugar Beets	2.9	2.5	3.6	3.9	69	64
Tomatoes	2.3	2.2	2.3	3.1	96	71
Vineyard	2.3	2.1	3.5	3.4	60	62

[1] State of California, Department of Water Resources, Vegetative Water Use in California, 1974 Bulletin No. 113-3, April 1975.

[2] Based on a rainfall zone with an average annual precipitation of 8-10 inches.

[3] Stewart, J. Ian, Irrigation in California. Report to the State Water Resources Control Board. June 1975.

[4] $\text{Efficiency} = \frac{\text{ET of Applied Water}}{\text{Applied Water}} \times 100$

To the best of our knowledge tailwater production has not been extensively measured and/or estimated. Table V-3, however, gives some estimates of tailwater production as percent of the applied water for different irrigation methods and crops. These runoff values reported are in general quite low. Perhaps they are indicative of rather ideal conditions (flat lands) for surface irrigation methods in much of the Central Valley.

D. Tailwater Control Practices and Reuse.

Tailwater management is rarely considered when irrigation water is inexpensive and plentiful and there is no problem with disposal of the runoff. On the other hand, increased tailwater management may be required in situations where there is 1) a shortage of water, 2) expensive water, 3) laws prohibiting or penalizing the disposal of runoff water, 4) pest problems (mosquito, weeds, pathogens, etc.), or 5) loss of crops due to flooding. There are two approaches to the management of tailwater. One deals with better control of the irrigation water, while the other uses physical means to handle the tailwater developed.

Better management of the irrigation water to increase irrigation efficiency and/or to reduce tailwater can come at the farm level alone or may be assisted by area-wide advisory services. The U.S. Bureau of Reclamation (USBR) and a few commercial companies are offering Irrigation Management Services (IMS) to farmers in some areas of California. Using weather, soil and crop data, the IMS program gives the farmer a periodic (weekly) report of the soil moisture status in his fields. It also suggests the next date of irrigation and amount of water that should be applied. At this time, the USBR offers this service to farmers within four irrigation districts in California, covering an area of 25,000 acres. The two commercial companies that offer IMS now are both operated out of the Fresno area, and provide their

Table V-3. Estimated irrigation tailwater production in the Central Valley.[1]

Crop	Irrigation Method	Percent Runoff of Applied Water (typical/range)[2]	
		Sacramento Valley	San Joaquin Valley
Irrigated pasture	Border strip, border check	15/0-30	15/10-30
	Sprinkler	5/2-10	--/0-5
	Wild flooding	35/30-50	
Alfalfa	Border strip, border check	5/0-20	
	Sprinkler	2/--	
	Furrow		--/0-2
Cotton	Furrow		<2/--
	Sprinkler		<2/--
Small grains	Border	<5/5-15	
	Furrow	5/5-15	
Rice	Basin, contour border	25/1-50[3]	
Sugar beets	Furrow	--/5-25	--/0-20
Grapes	Furrow, sprinklers		~0
Almonds, walnuts	Sprinkler	~0	~0
	Border, furrow, basin	10/0-20	5/0-20
Peaches, nectarines	Sprinkler	~0	~0
	Border, furrow, basin	~0	~0
Tomatoes	Furrow	--/0-20	--/0-25
	Sprinkler	~0	
Other vegetables	Furrow	5/--	~0/0-25

[1] Private communication, Dr. Ian Stewart.

[2] Unreported typical runoff or range of runoffs are designated by a dash symbol.

[3] Glenn-Colusa Irrigation District.

services to farms covering over 50,000 acres. While the implementation of IMS is expected to reduce water use in general, it is designed to optimize water use, not reduce tailwater. In fields where overuse of water was the common practice, tailwater and subsurface drainage will be reduced using the IMS suggested values of water application rates. At the same time, there will be fields that did not receive enough water, and the IMS program will call for increased irrigation. This will lead to increased tailwater and subsurface drainage.

While IMS provides a great deal of help in irrigation planning, it is the on-farm handling of the water that determines the amount of tailwater produced. Whether or not the farmer is using IMS, he can usually reduce tailwater-related problems through better on-farm management of the irrigation water. As noted earlier, different methods of irrigation produce varying amounts of runoff. Even when managed properly, some methods of irrigation must produce large amounts of tailwater in order to provide uniform application of water, while other irrigation methods may produce little or no runoff. Selecting the correct stream size for the crop, soil and slope of the field will do a great deal in reducing the amount of tailwater produced. Reducing the irrigation stream part way through the irrigation (cut back irrigation) may be necessary to get maximum efficiency out of the water and reduce the tailwater production. The level of irrigation management implied by IMS and "cut back" irrigation is not commonly practiced due to the high cost of the labor and services involved.

If the increased cost of irrigation management is high, or the control of tailwater through management of irrigation water is inadequate, physical control systems may be the alternative. Like irrigation systems, tailwater control systems are engineered to fit the needs of the specific situation. Their main function is to remove the tailwater from the field and deliver it to a point of reuse or disposal. While drain ditches at the bottom ends of fields are common, the loss of water through inefficient irrigation is very costly where water is scarce or expensive. In situations where the tailwater cannot be used on a lower field, an on-farm tailwater return system may be feasible. A typical tailwater return system consists of collection, storage, pumping and transport facilities used to return the tailwater from a field to the irrigation water supply. A common way of doing this is to construct a ditch that runs down slope along the lower end of the field and drains the water to the lowest point in the field. At the end of the ditch a sump is constructed to hold a substantial portion of the runoff from the field. A small pump is located next to or over the sump and pumps the runoff water via a closed pipeline back to the irrigation distribution system at the upper end of the field. In most cases, the water is returned to the supply for the same field from which it came, but it could also be pumped to another field in the area. As noted, there are no specific rules to follow in the design of tailwater return systems but they can be classified by sump size. Where land is expensive, the sump size is often kept to a minimum. This requires a rapidly cycling pump that returns water to the supply system throughout the period of irrigation. This type of tailwater recovery system requires an irrigation supply system that can accept the periodic additions of tailwater without changing the water application rate. In other areas such as pastures, the sump can be built to hold quite a bit of the tailwater. In this way, it can be stored for use in supplementing the irrigation of whole sections of the field at once. The farmer can wait until the sump contains adequate water and then he will have a steady flow once the pump is started. The Soil Conservation Service (SCS), which offers the service of designing tailwater return systems for individual farms, uses the following rules of thumb for the design of the latter type of system: The sump should be large enough to hold the irrigation runoff from at least 24 hours of surface irrigation. They figure that 20 to 25 percent of the water applied will usually run off the bottom end of the field. The pump must be able to pump at the maximum inflow rate. While the size of the pump will vary according to the size of the field, irrigation method, and the head it is pumping against, they are usually under 10 hp.

While on-farm tailwater recovery systems may be the only alternative for farmers supplying their own water, other alternatives are open to irrigation districts and other organizations. For example, the Broadview Water District collects tailwater as well as the outflow from the tile drainage systems in one drainage canal system. These combined waters flow by gravity to the low point of the district and are pumped back into the main supply canal which happens to enter the district at the same low point. While this system would work better if the lower quality tile drainage was not included, it does provide for more complete consumptive use of all of the water that enters the district. However, it should be pointed out that a potential danger exists with regards to salt balance in Broadview Water District. In other areas the tailwater is picked up and returned to supply canals at several points within or even outside the district.

When tailwater recovery and reuse are not needed, there may be other problems that must be dealt with before the water can be disposed of. The Byron-Bethany Irrigation District had so much trouble with silt that they now require that all tailwater, excluding runoff from alfalfa and permanently irrigated pastures, flow through settling tanks prior to disposal into district canals.

In summary, the alternative tailwater management practices, as shown in Figure V-1, are:

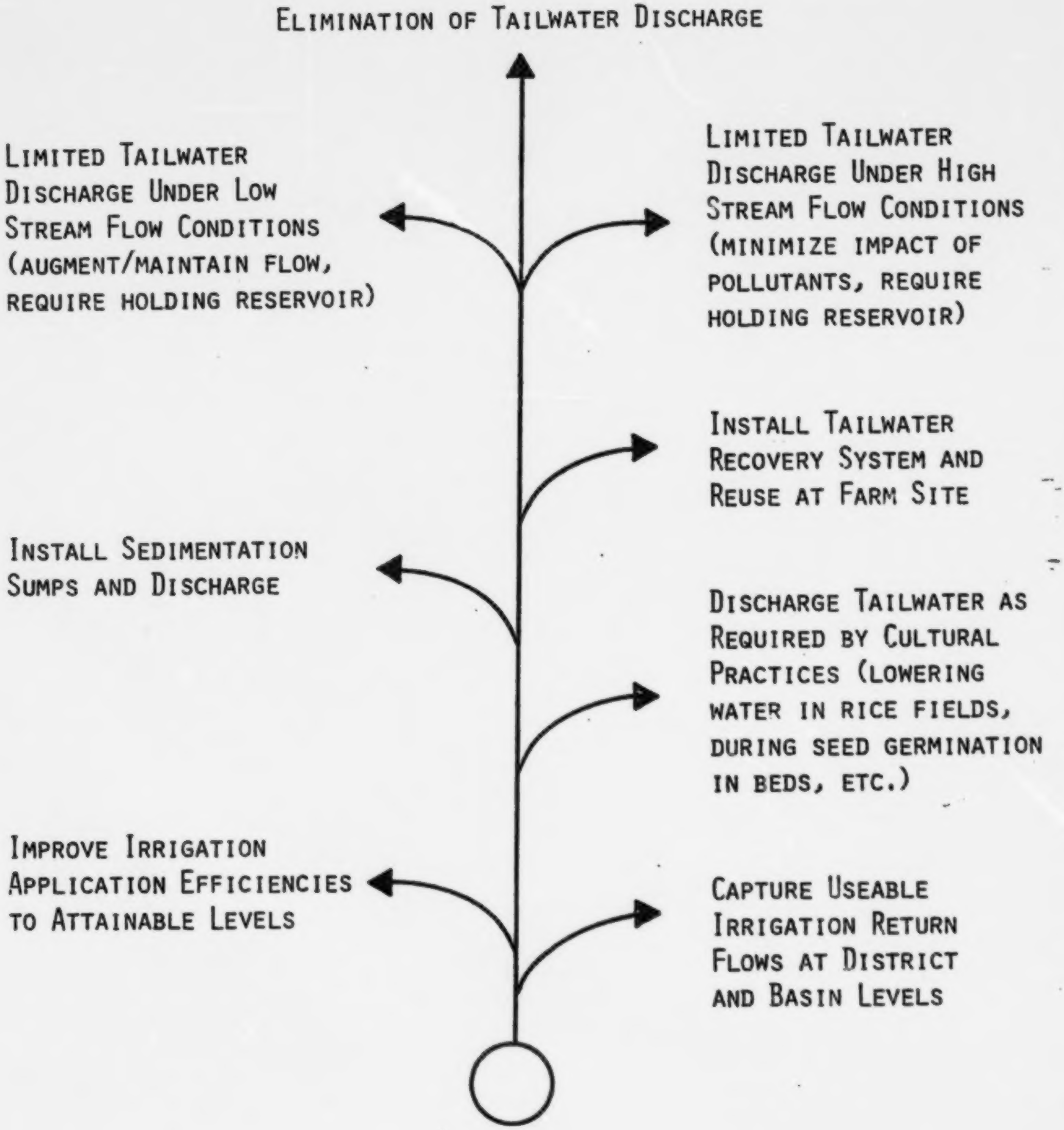
ELIMINATION OF TAILWATER DISCHARGE
LIMITED TAILWATER DISCHARGE UNDER LOW STREAM FLOW CONDITIONS (AUGMENT/MAINTAIN FLOW, REQUIRE HOLDING RESERVOIR)
LIMITED TAILWATER DISCHARGE UNDER HIGH STREAM FLOW CONDITIONS (MINIMIZE IMPACT OF POLLUTANTS, REQUIRE HOLDING RESERVOIR)
INSTALL TAILWATER RECOVERY SYSTEM AND REUSE AT FARM SITE
INSTALL SEDIMENTATION SUMPS AND DISCHARGE
DISCHARGE TAILWATER AS REQUIRED BY CULTURAL PRACTICES (LOWERING WATER IN RICE FIELDS, DURING SEED GERMINATION IN BEDS, ETC.)
IMPROVE IRRIGATION APPLICATION EFFICIENCIES TO ATTAINABLE LEVELS
CAPTURE USEABLE IRRIGATION RETURN FLOWS AT DISTRICT AND BASIN LEVELS

FIG. V-1: ALTERNATIVE TAILWATER CONTROL PRACTICES

1. Recover useable tailwater and other irrigation return flow components on district/regional levels.
2. Improve irrigation application efficiencies to attainable levels.
3. Discharge tailwater only as required by cultural practices, such as the lowering flood water depths in rice fields to prevent erosion of levees and prior to harvesting, spilling of sodium-affected flood water from rice fields, and during seed germination in furrow beds.
4. Install sedimentation sumps or other sediment settling practices to reduce sediment load and associated pollutants, and allow discharge.
5. Install tailwater recovery system and reuse at farm site.
6. Allow for limited tailwater discharge under low stream flow conditions to augment/maintain flow.
7. Allow for limited tailwater discharge under high stream flow conditions to minimize the impact of pollutants being discharged.
8. Prohibit tailwater discharge.

The technology to control tailwater is available, but in some cases the systems or water controls needed are so costly that current conditions do not justify them. If water becomes relatively more expensive or unavailable, more reuse of tailwater will be seen. The farmer or the irrigation district will have to determine which type of tailwater management will best serve their needs.

VI. FACTORS AFFECTING TAILWATER QUALITY

Tailwater is defined as surface runoff derived from applied irrigation water. By contrast, water that has entered the soil to reappear as surface water is considered drainage water. Because of additional processes that occur in the soil, the drainage water quality will be different from that of tailwater. Comparisons of supply water, tailwater, and drainage water quality are useful for evaluating changes which occur during use. In some cases tailwater quality may actually be improved by irrigation use over that of the applied water by virtue of the removal of suspended solids or reduction in nutrient concentration. Consequently, it is not correct to assume that tailwater quality will always be lower than the applied water. Some parameters may reflect a decrease in quality while others will reflect an increase and it is therefore important to evaluate those significant parameters that will have a bearing on the reuse of the water. Furthermore, it is important to recognize that in some instances it is the mass emission of a constituent that may be more significant rather than the concentration. In such cases the quality parameters must be flow weighted. Tailwater contains inorganic salts which may range from insignificant to major increases in concentration over that of the applied water, depending upon factors which involve the soil, crops, management and rate processes that occur. Nutrient constituents such as nitrogen and phosphorus may show increases or decreases, and other chemicals such as pesticides may also be variable. Likewise, as previously stated, suspended solids may decrease as well as increase during water use.

A. Tailwater Quality Constituents

Salinity

Evaporation of water from the soil surface and transpiration of water by plants (ET) concentrates the soil solution and promotes salt accumulation in the soil surface and within the root zone between irrigations. With subsequent application and flow of water over the soil surface some of the accumulated salt will dissolve and increase the concentration of constituents in the tailwater. The magnitude of salt pickup by this process will depend upon the infiltration of water and dissolution of salts during the initial phase of the water application since salts that are leached into the surface soils by the initial infiltration are unlikely to appear in the tailwater. Salts that are slowly soluble are likely to contribute less to tailwater salinity simply because the period of tailwater production is of fairly short duration. The salinity of the supply water will have a significant effect on the salinity of the tailwater, the former limiting the minimum salinity attainable in the tailwater as well as providing the source of salt that may accumulate in the soil with time. Other conditions specific to a given location will also affect the quality of the tailwater. Tailwater from rice culture is often characterized by a very small to essentially no increase in salinity, depending upon the residence time of the water in the field and the evaporative conditions.

A summary of changes between applied and tailwater quality in rice test plots in the Glenn-Colusa Irrigation District, located in the Sacramento Valley, is given in Table VI-1. The values shown are not flow weighted, however, it is evident that the EC and TDS values in the tailwater show from no increase to increases of less than two times over the applied water for the fields investigated.

Similar changes were observed in a tomato test field in the Panoche Water District in the San Joaquin Valley as shown in Table VI-2. In both locations the quality of the tailwater as represented by EC is suitable for reuse on most crops and would be expected to have little impact on receiving

Table VI-1. The average quality of applied and tailwater from rice test plots in the Glenn-Colusa Irrigation District, April-September, 1975.

Test Area		Field 4 (139 ac)	Field 14 (153 ac)	Field 8 (141 ac)	Field 15 (61 ac)
EC (μmhos/cm)	In[1]	148	144	152	388
	Out	135	229	160	578
TDS (mg/ℓ)	In	98	95	102	231
	Out	99	140	110	333
Turbidity (JTU)[2]	In	17	12	20	34
	Out	37	9	6	17
SS (mg/ℓ)[3]	In	37	16	21	42
	Out	43	16	16	37

[1] In refers to applied water.
Out refers to tailwater.

[2] JTU is Jackson turbidity units.

[3] SS is suspended solids.

Table VI-2. The average quality of applied and tailwater in a furrow irrigated tomato test field in the Panoche Water District (PWD), July, 1975.

	EC (μmhos/cm)	Turbidity (JTU)
Supply water (PWD 4T)	389	104
Supply water (check 32)	425	104
Tailwater (checks 27-32)	510	1,375

waters. In fact, the mixing of tailwater with tile drainage effluent at another location in the Panoche Water District demonstrates a significant upgrading of the poor quality of the drainage water to the extent that the mixed water is suitable for reuse.

In contrast to tailwater EC and TDS, drainage water from this same district as well as others in the area reveal much larger EC values, ranging between 1,500 to 11,000 μmhos/cm and TDS of 1,500 to greater than 8,000 mg/ℓ. On the other hand, for drainage waters in the Glenn-Colusa Irrigation District, where rice is a principal crop, the EC values are similar to tailwater with maximum values of the order of 600-700 μmhos/cm and TDS in the 200-400 mg/ℓ range.

Tailwater quality rarely reflects significant increases in the boron concentration over that of the supply water and in most cases the concentration is less than 0.5 mg/ℓ and usually less than 1 mg/ℓ. Consequently, most crops would not be affected by reuse of such water. By contrast some drainage waters do show significant increases in boron content to the extent that it becomes toxic to plant growth and dilution would be necessary for reuse. Such a contrast is to be expected since boron is often fixed in the soil and not readily redissolved in surface runoff.

Suspended Matter.

Water moving over the soil surface often erodes the soil and transports both soil and other litter in a suspended form with it. This suspended matter, which is both organic as well as inorganic in composition, increases the turbidity of the water, thereby modifying the light transmission characteristics of the water. In terms of mass constituents, the suspended matter becomes the sediment that is deposited elsewhere. Extensive investigations have been conducted for several years to identify those properties of soils and related environmental conditions which can be used to explain and predict the erodibility of soils. Clearly, soil properties, management practices, topographic features and other variables are involved in a complex way. The nature of the suspended matter, electrolyte (salt) concentration of the water, flow velocities, length and slope of run partially determine the length of time suspended matter remains in a mobile form before sedimentation occurs. For these various reasons some constituents of suspended solids have long residence times in surface runoff and other constituents sediment rather quickly. Consequently the measurement of mass of suspended solids and turbidity often may represent different transient properties of the system.

Comparisons of tailwater suspended solids and/or turbidity with these parameters in the applied water may often show a decrease in their values as water filters through vegetative matter on the soil surface, i.e., the water quality is improved by irrigation use. This is illustrated in Table VI-1, for tailwater from the rice test plots where three of the four fields show a decrease in turbidity when comparing applied and tailwater. The turbidity in Jackson turbidity units (JTU) ranged from 6 to 37 with the latter value being within quite acceptable limits. The change in suspended solids (SS) between applied and tailwater ranged from no change to a slight decrease in one field and a slight increase in another. Increases of suspended solids in rice culture may be associated with growth of aquatic plants (free floating) in the water as well as or in lieu of erosion.

At the tomato test site (Table VI-2) the turbidity of the supply water was much higher at 104 JTU and a significant increase was observed in the tailwater with an average value of 1,375 JTU. Maximum values of 2,800 JTU were observed in this field. The tailwater from this field, however, was not discharged but was captured in a sump and reused. The turbidity of the recirculated water ranged between 275 and 300 JTU.

Drainage waters from tile drained fields will generally be clear and devoid of suspended solids in contrast to tailwater. However water that is captured in open drains often exhibits both turbidity and suspended solids. Some of the suspended matter is derived from tailwater, some from aquatic growth, and some from erosion of ditch banks as well as that which settles from wind erosion. Consequently open drains in the districts in the San Joaquin Valley exhibit turbidity values ranging from 40 to 400. Open drains may also provide an opportunity for removal of suspended matter. The presence of higher electrolyte concentrations in these drains often is conducive to settling out of the suspended matter since some soil material is more readily flocculated at higher salt concentrations. This could also be an important factor in the erosion of soil during irrigation.

In addition to the reduction in light transmission characteristics of suspended matter in water, suspended matter may present problems in the reuse of water if mechanical damage to pumps, clogging of orifices and deposition of suspended matter on plant foliage occurs.

Nutrients.

Nutrients in tailwater that may be of concern include a broad list that encompasses both micronutrients and the more commonly recognized fertilizer compounds of nitrogen and phosphorus. It is on the fertilizer compounds that attention will be focused.

Nitrogen.

Nitrogen may appear in tailwater in both organic and inorganic forms. The inorganic forms, NH_3, NH_4^+, NO_2^-, and NO_3^- are more easily identified, and analyses of waters frequently provide concentrations of these forms if present. Concern for excessive concentration of these constituents may involve their potential for accelerating eutrophication of water and toxic effects to specific organisms that may be exposed to these forms.

Because of its toxicity to certain organisms a limit of 0.4 mg/ℓ of unionized NH_3 has been set with an overall limit of 0.5 mg/ℓ as ammonia-N in public water supplies. Ammonia is also known to be corrosive to certain metals and if present decreases the disinfecting efficiency of chlorine added to water through the formation of chloramine compounds.

Nitrite is known to be toxic to organisms at low concentrations and a limit of 1 mg/ℓ has been set for public water supplies. Nitrate presents a toxic hazard to infants because methemoglobinemia and the limit in public water supplies has been set at 10 mg/ℓ NO_3-N. Nitrate has also been identified as a stimulator of algal growth which decreases the aesthetic quality of water and increases the cost of water treatment. Where eutrophication appears to be a problem, a limit of 0.5 mg/ℓ nitrate has been suggested. For watering livestock and poultry, the combined concentrations of NO_2- and NO_3-nitrogen should not exceed 100 mg/ℓ or in the case of NO_2^- alone the limit has been set at less than 10 mg/ℓ of NO_2-N.

The presence of organic matter in water is of interest because of the demand placed on oxygen in the water during the breakdown of the organic compounds and the subsequent release of inorganic forms of nitrogen. In some cases the presence of organic matter adds to the turbidity of water and may often be identified also as suspended solids. However the measurements of turbidity and suspended solids do not specifically identify the nature of the constituent and the concentration units of these measurements are therefore not expressed in terms of the organic nitrogen if these compounds do indeed contribute to suspended solids and turbidity.

Various studies of the concentration of nitrogenous compounds in tailwater would appear to substantiate the foregoing remarks. In the Glenn-Colusa Irrigation District studies it was shown that the mass emission of nitrogen in tailwater from rice culture is approximately 14% of the nitrogen entering the fields. In other words, the concentration of nitrogen has been reduced during irrigation and an upgrading of the water quality has resulted with respect to nitrogen parameters.

Rarely did any of the forms of nitrogen (organic, NH_4, NO_3) exceed 3 mg/ℓ in the tailwater and the total nitrogen usually was less than 4 mg/ℓ. While extensive data of nitrogen compounds in tailwater is presently not available from our San Joaquin Valley study locations, analysis of drain waters which may represent water from many sources also demonstrate total N concentrations of less than 5 mg/ℓ with individual constituents often not exceeding 0.1 mg/ℓ. In the Los Banos Wildlife Area which receives drainage water from many sources and in addition has extensive wildlife population, the values of total N and organic N may range up to 10 mg/ℓ but the outflow total N concentration is about 2 mg/ℓ. A tentative conclusion would suggest that nitrogen compounds in the drainage water and certainly the tailwater would present no environmental hazard or degradation potential to receiving waters.

Phosphorus.

Phosphorus exists in soils both in organic and inorganic forms. However the soluble forms most subject to leaching are mainly inorganic. Since most of the P in soils exists as compounds of low solubility or in a fixed (adsorbed) state, the concentration of soluble phosphorus in the soil solution is quite low, usually less than 1 mg/ℓ. For this reason the amount of phosphorus subject to leaching to reappear as drainage water will usually be less than 1 mg/ℓ.

On the other hand, the erosion of surface soils may add to the concentration of phosphorus in surface runoff and tailwater in addition to some dissolution into surface water flow. The forms of phosphorus are likely to include both inorganic and organic forms, with the latter being associated with organic matter and sediments. While the soluble inorganic forms are considered to be immediately available biologically, the organic and adsorbed phosphorus are less available. For this reason it is the soluble inorganic P in tailwater that is likely to be of most concern. This concern is related to the stimulations of aquatic growth in waters rather than any health hazard. Various studies appear to substantiate the fact that surface runoff and erosion contribute more P to waters than percolated waters other things being equal. A comparison of the major pathways of nitrogen and phosphorus movement to surface waters would therefore indicate that a major portion of the nitrogen is leached and appears in drainage water because of the soluble forms of nitrogen whilst the major pathway of phosphorus is by surface flow and erosion.

Although no specific data are available on the concentrations of P in supply, tail and drainage water in this study, other studies of P in subsurface drainage waters in the San Joaquin Valley report ranges of orthophosphate between 0.02 and 1.90 mg/ℓ with an average concentration of 0.2 mg/ℓ or equal to or less than the naturally occurring levels in surface waters. (San Joaquin Valley Drainage Monitoring Program, Summary Report: 1974, Department of Water Resources.) Other reports summarized by Biggar and Corey (Eutrophication: Causes, Consequences, Correctives, 1969) indicate that erosion of surface materials may be a major source of P in surface waters in contrast to drainage water.

Pesticides.

Pesticides include a great many organic compounds, many of which are not found naturally in the environment. They differ widely in their chemical and toxicological characteristics. Therefore they differ widely in their behavior in the environment and their impact on the environment.

Pesticides are often categorized as to the target organism they are intended to control, for instance insecticides, herbicides, fungicides, etc. For other purposes they are grouped as to their chemical nature such as organochlorines, organophosphates, carbamates, triazines, substituted ureas and so forth. Their physical and chemical properties cover a wide spectrum. They range from insoluble to very soluble in water. Some are volatile and others nonvolatile. Some are strongly adsorbed in the soil and organic matter while others are not. Their resistance to microbial degradations is also broad and some are photochemically degraded, while others are insensitive to these processes.

The concern for these compounds resides almost entirely in the realm of their toxic effects on organisms. These concerns include immediate effects, chronic effects and reaction due to bioaccumulation, the latter two often not mutually exclusive.

Because of the complexity of the system involved, it is difficult to broadly group these compounds and this is borne out by the extensive tables that have been developed expressing the acceptable limits of concentrations of each compound in waters, plants and soils. The appearance of pesticides in tailwater will depend upon a number of factors previously mentioned. If they are present in surface soils, some will dissolve and appear in the tailwater. Surface erosion of organic and mineral soil constituents may further contribute to their concentrations in surface runoff. Aerial applications accompanied by drift and volatilization may also contribute to the presence of some compounds in surface waters either during application of water and chemicals or during later periods. Inadvertant spillage or careless handling of containers, spray rigs and so forth have also been identified as sources of contamination. Nevertheless, it has been observed that variable concentrations of pesticides have been found in surface runoff, although the source and pathway are not clearly identified.

In the present study no data has been collected relative to the concentration of pesticides in supply, tail or drainage water. However, the 1974 drainage monitoring report of the Department of Water Resources gives variable concentrations of chlorinated hydrocarbons ranging from 4-3,000 μg/ℓ with averages in the 100-350 range for subsurface drains during 1974. Concentrations were generally higher in surface compared to subsurface drainage waters. Organic phosphorus compounds were also found in surface drainage effluents.

Johnston et al. (Proc., Soil Science Society of America, Vol. 29, 1967) reported that tailwater and surface runoff contained 7-12 times more DDT residue than applied water although higher concentrations were found in open drains.

Based on the previous discussion, it appears that erosion of surface soils may contribute pesticide to tailwater and surface drains with additional inputs to the latter being derived by other mechanisms such as drift.

Other Parameters.

Dissolved oxygen (DO) in water is an important parameter with respect to aquatic life. Depletion of dissolved oxygen may limit the activity of oxygen-requiring aquatic organisms and could lead to extinction when excessive DO depletion occurs. A limited number of measurements of DO in drainage waters in the EPA project generally indicate a range between 8-10 mg/ℓ which encompasses values that are in equilibrium with the atmosphere. In the Los Banos Wildlife Area, however, a few very low concentrations were measured suggesting oxygen demanding processes were present which depleted the DO. This might be expected in view of the contribution of oxygen demanding wastes by wild fowl and sewage.

Biochemical oxygen demand (BOD) measurements are often used as an indicator of the oxygen that will be required to degrade organic wastes. Sewage effluent that has received secondary treatment often has a BOD of 20-30 mg/ℓ while many other water sources have a range of from 1-3 mg/ℓ. In the present study drainage waters in the Los Banos Wildlife Area yield values ranging from 2-5 mg/ℓ. While these values are relatively small they probably reflect, to some extent, sources of organic wastes derived from sewage and/or the impact of wild fowl and native vegetation on the surface water.

B. Effect of Tailwater on Surface Water Quality.

The impact of tailwater on surface water quality will depend upon a number of factors discussed in the previous section. Certainly the volume of tailwater relative to the volume of the receiving water will be a factor. Since several parameters determine the quality of a water, it is conceivable that tailwater will improve the receiving water relative to some parameters and degrade it relative to other parameters. In general it is to be expected that tailwater salinity will increase over that of the applied water but may not contain necessarily a higher TDS than the subsequent receiving water, especially if the latter is derived from subsurface flow. Tailwater that has been derived from supply water of low salinity will usually be of sufficiently good quality in TDS to allow direct reuse, and may not contribute significantly to the degradation of surface water. On the other hand, with continued recycling of such water it will inevitably increase in salinity.

The amount of nitrogen and phosphorus in tailwater will partly depend upon the amount of soil erosion that occurs during use. Erosion will enhance the removal of phosphorus which otherwise will be similar to the supply water and probably will not be significantly different from natural runoff. Soluble nitrogen compounds will be generally low in tailwater with organic forms reflecting the effect of erosion and vegetative residues.

Total suspended solids and turbidity in tailwater will also reflect erosion processes whether they occur during irrigation or in subsequent collection facilities. The impact suspended solids have on surface waters will, therefore, to a large extent reflect the erosion potential of the land surface. Suspended solids derived from natural runoff in some cases may equal or exceed that derived from tailwater. Management to minimize suspended solids in tailwater is much more realistic than control of salinity and can often be utilized to improve the quality of supply or surface waters. Furthermore, when flows are low in some surface streams, the addition of tailwater to augment its flow may actually represent an improvement in the resource.

VII. SAN JOAQUIN VALLEY FIELD STUDIES

The selection of field study sites was closely coordinated with the California Regional Water Quality Control Board-Central Valley Region, the Mendota-Crows Landing Return Flow Group, and the Sacramento Valley Water Quality Committee. The latter two water user's organization are California's first National Pollutant Discharge Elimination System (NPDES) permittees for discharge of irrigation return flows.

A. Mendota-Crows Landing Return Flow Group

The Mendota-Crows Landing Return Flow Group consists of 17 entities representing water and drainage districts, canal companies, wildlife and grasslands areas, and individual landowners. It encompasses 400,000 acres on the west side of the San Joaquin Valley in Merced, Fresno, and Stanislaus Counties. The coordinator of this return flow group is Mr. C. W. Bates, Secretary-Manager of the Central California Irrigation District (CCID), and assisting Mr. Bates is Mr. Timothy McCullough, Assistant to the Manager, also of CCID. On July 25, 1975, this return flow group received an NPDES permit to discharge irrigation return flows into the middle reaches of the San Joaquin River. This initial permit expires on July 25, 1977.

Figure VII-1 shows the area encompassed by the Mendota-Crows Landing Return Flow Group. This group is bounded on the west by Highway Interstate 5, the California Aqueduct and the Delta-Mendota Canal, on the east by the San Joaquin River, and on the north and south by Crows Landing and Mendota, respectively. The major source of supply water is imported via the Delta-Mendota Canal, as part of the U.S. Bureau of Reclamation's Central Valley Water Project. Water is delivered initially to the Mendota Pool and then distributed in a northeasterly direction from the Mendota Pool by several canals. Other minor sources

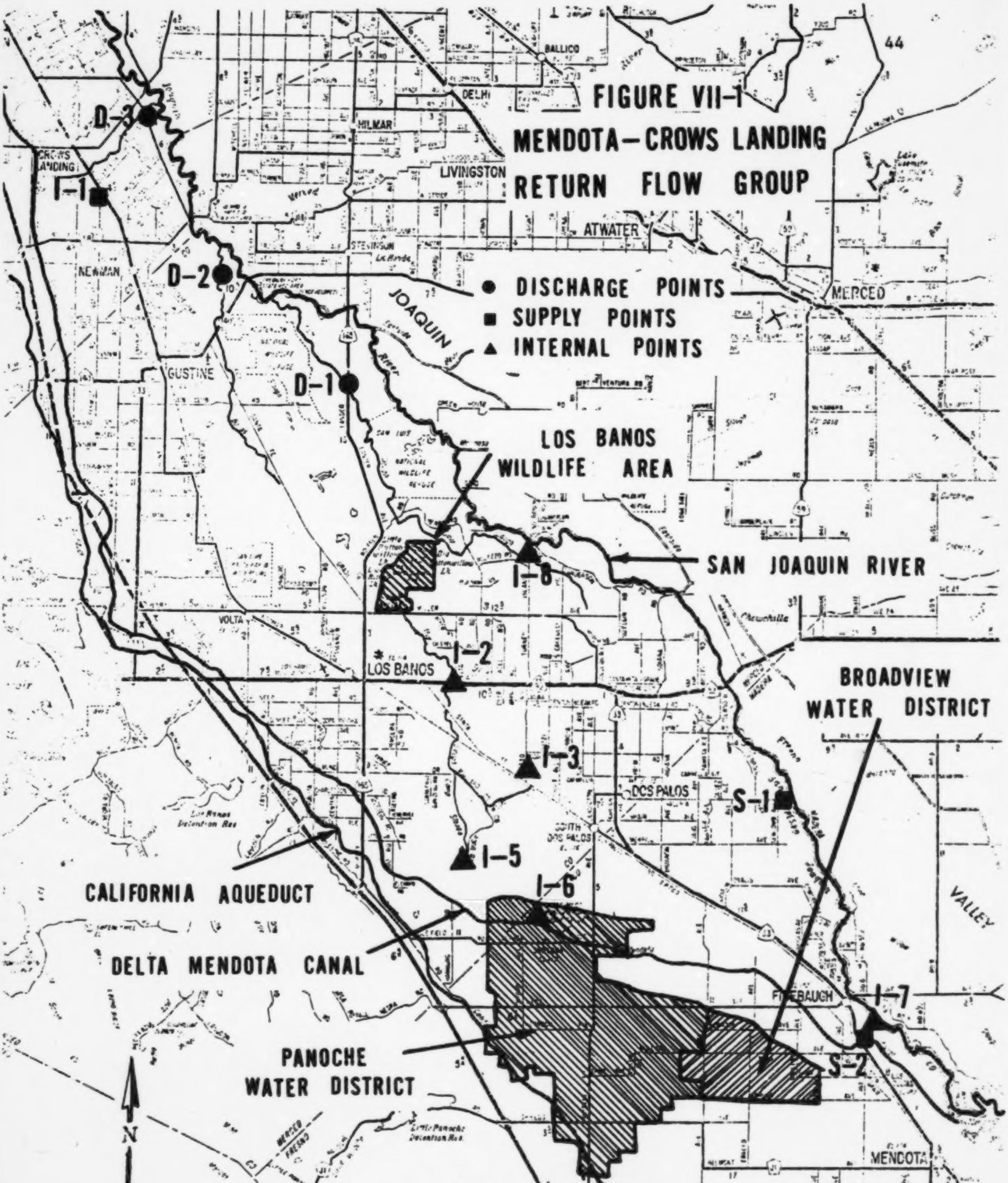

FIGURE VII-1 MENDOTA–CROWS LANDING RETURN FLOW GROUP

● DISCHARGE POINTS
■ SUPPLY POINTS
▲ INTERNAL POINTS
D-3
D-2
D-1
I-1
I-2
I-3
I-5
I-6
I-7
I-8
S-1
S-2
CROWS LANDING
NEWMAN
GUSTINE
HILMAR
DELHI
BALLICO
LIVINGSTON
STEVINSON
ATWATER
MERCED
VOLTA
LOS BANOS
DOS PALOS
SOUTH DOS PALOS
FIREBAUGH
MENDOTA
JOAQUIN
LOS BANOS WILDLIFE AREA
SAN JOAQUIN RIVER
BROADVIEW WATER DISTRICT
CALIFORNIA AQUEDUCT
DELTA MENDOTA CANAL
PANOCHE WATER DISTRICT
VALLEY
Los Banos Detention Res
Little Panoche Detention Res
MERCED
FRESNO
N

of irrigation water are pumped groundwaters, the California Aqueduct, and recaptured return flows. The general direction of drainage is eastwards from the alluvial fans in the west towards the basin rim, and northeasterly in the valley floor and lower alluvial fans.

This return flow group has a permit to discharge irrigation return flows from Salt Slough (D-1), Mud Slough North (D-2), and Orestimba Creek (D-3). The Group is required to monitor and report water flows (Q), electrical conductivity (EC), and suspended solids (SS) on a weekly frequency during the irrigation season. The Group also monitors and reports Q, EC, and SS of its supply waters at the head of Arroyo Canal in the San Joaquin River (S-1) and in the Delta-Mendota Canal at the Firebaugh Wasteway (S-2) on a monthly basis.

Cooperative arrangements have been made with the NPDES permittee to obtain water samples for quality analyses and flow measurements. In addition to EC and SS, our project is also determining total dissolved solids (TDS), turbidity in Jackson Turbidity Units (JTU), and boron. More detailed analyses are carried out several times a year for the dissolved mineral salt constituents, various nitrogen species, and biochemical oxygen demand (BOD).

In addition to the NPDES monitoring stations, this project has seven internal stations (Fig. VII-1) in the drainage and/or supply network, upstream from the NPDES discharge stations. Flow is being estimated wherever possible, and quality data similar to that obtained for the NPDES stations are being collected on a monthly basis.

The above represents the water quality survey for this return flow group. Other spatial evaluations are also being conducted; namely, at the district and on-farm levels. Individual entities within the return flow group being studied are the Broadview and Panoche Water Districts, and the Los Banos Wildlife Area (Fig. VII-1). On-farm studies being conducted in the Panoche

Water District consist of a 170-acre field equipped with a tailwater recovery system and cropped to furrow-irrigated tomatoes in the 1975 irrigation season; and a 1,700 acre tile-drained field in which tile spacing is progressively being decreased from 600 to 300 ft and which utilizes a blend of freshwater, surface runoff, and tile drainage effluent for irrigation.

Water quality and flow data for this return flow group are tabulated in Appendix Tables 1-13. Table VII-1 contains a list and description of the NPDES and EPA monitoring stations, along with seasonal Q in ac-ft and the seasonal average of selected quality parameters. It should be mentioned that although monitoring is proceeding year-round, this report covers only the "monitored irrigation season" from May through October of 1975. In actuality, the irrigation season in this area may commence as early as January or as late as April, and may terminate as early as October or extend into December, depending upon winter rainfall and the need to renovate the supply distribution system. But for this annual report, the "irrigation season" will encompass our initiation of this study through October. The NPDES supply and discharge stations presumably include the major supply and discharge points, but they do not represent the total supply nor the total discharge. Thus, it is not possible to fully appraise the mass inflow and mass outflow of salinity, suspended matter, or other parameters in this return flow group.

Table VII-1 points out that the quality of discharge waters from the NPDES stations is different. Substantial increases in salinity (EC,TDS) are noted for D-1 and D-2, over that of S-1 and S-2. These increases in salinity are attributed to the concentrating effect of evapotranspiration; i.e., pure water (more or less) is lost to the atmosphere while salts present in the applied irrigation water remain in the soil. In addition salt pickup can occur from the chemical weathering of soils, some of which are salt-affected

Table VII-1: NPDES and EPA Monitoring Stations in the Mendota-Crows Landing Return Flow Group for the May through October 1975 Irrigation Season.

Station	Description	Quantity[*] (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)
NPDES Supply Stations							
S-1	Arroyo Canal	131,166	502	278	33	118	0.18
S-2	Delta-Mendota Canal	793,629	468	205	41	107	0.22
NPDES Discharge Stations							
D-1	Salt Slough	46,022	1,462	821	35	91	0.56
D-2	Mud Slough North	5,129[‡]	1,933	1,208	56	97	1.64
D-3	Orestimba Creek	7,501	621	374	305	572	0.25
EPA Internal Stations							
I-1	CCID Main Canal[†]	-	878	507	35	63	0.46
I-2	Mud Slough South	-	2,085	1,336	37	83	2.61
I-3	Bennet Drain	-	2,977	1,798	32	73	1.15
I-5	Camp 13 Slough	-	3,008	1,993	90	258	4.16
I-6	Panoche District Drain	19,458	3,070	2,053	126	348	4.82
I-7	Firebaugh Wasteway[†]	-	924	567	53	121	0.58
I-8	Turner Island Intake[†]	14,937	890	511	51	136	0.14

[*] If water flows are available, quality parameters are flow-weighted averages; and if not available, quality parameters are simply seasonal averages.

[†] Also supply source.

[‡] July 1-October 29, 1975.

in this area. Station D-3 is different since its flows consist of operational spills, together with irrigation return flows from croplands.

Furthermore, the suspended matter (turbidity and SS) is substantially higher for D-3 than other NPDES stations. The large suspended load in Orestimba Creek is probably due to a steeper gradient than in Salt Slough or in Mud Slough North, resulting in a greater current velocity. This keeps sediments in suspension and/or picks up silt and clay laid down in the creek bed during winter runoffs from the Coast Range watershed. Other sources of sediments are tailwater runoffs from row crops. In addition to the slower current velocities in Salt Slough and Mud Slough North, the suspended load is smaller since a significant amount of the suspended load in the irrigation return flow is deposited in grassland and wildlife areas, where reuse takes place.

The boron concentration at D-3 is similar to that of the supply water, while boron was substantially higher at D-1 and D-2 due to the leaching of boron-affected soils in the area. Soil salinity and soil boron data are presented later, in the district-level assessments.

Internal stations I-1, I-7, and I-8 in the drainage network also provided supply waters for the low-lying croplands, grassland, and wildlife refuges. These waters are approximately twice as saline as the fresh supply water found in the Delta-Mendota Canal (S-2). Boron is also higher at I-1 and I-7, as compared to S-2. Suspended matter is extremely high in I-8, as compared to other irrigation return flows. Other more saline-high boron drain waters (I-2, I-3, I-5, and I-6) were discharged into Salt Slough and Mud Slough North or their tributaries, and reused in pastures and wildlife habitats before final discharge into the main drains. Note that the salinity in these drains is about 4.5 to 6.6 times greater than S-2, and boron ranges from 1.2 to 4.8 mg/liter.

For illustrative purposes, Figure VII-2 plots the temporal changes in Q, EC, and SS for supply station S-2, and a similar plot is given in Figure VII-3 for the discharge station D-1. The peak flow in S-2 occurred in midsummer (from June through August). In contrast, the peak flow in D-1 was from mid-August to early September. Some of the contributing factors to the lag time noted between delivery and discharge are drainage of rice fields prior to harvest, travel time through soils and collection as return flows in canals, and the reuse and discharge of waters from the wildlife and grassland areas.

Monthly measurements of EC of the supply water were low, except for August. It is known that EC varies widely in the Delta-Mendota Canal and that monthly grab samples may not be truly representative (see Appendix Fig. 1). These variations in EC may be attributed to the variations in the outflow from the Sacramento and San Joaquin River systems, and sea water intrusion into the Delta which is partly influenced by tidal movement. The EC of discharge water was consistently higher by about 3 to 4 fold of magnitude, except in October, when discharge decreased substantially (due to the filling of duck ponds) with a concurrent rise in EC. The supply water contains a moderate amount of suspended matter, and is quite turbid. The discharge water has a similar suspended solid load, and appears to be lower than that of the supply water in mid to late October, probably reflecting the deposition of silt in the reuse areas.

Figure VII-4 shows EC to be inversely proportional to Q, while Figure VII-5 shows SS to be directly proportional to Q. Presumably, at low flows, EC is higher than at high flows due to the predominance of subsurface drainage water over that of surface runoffs. Surface runoff is a major contributor to return flows and has lower EC than subsurface drainage or discharges of reused

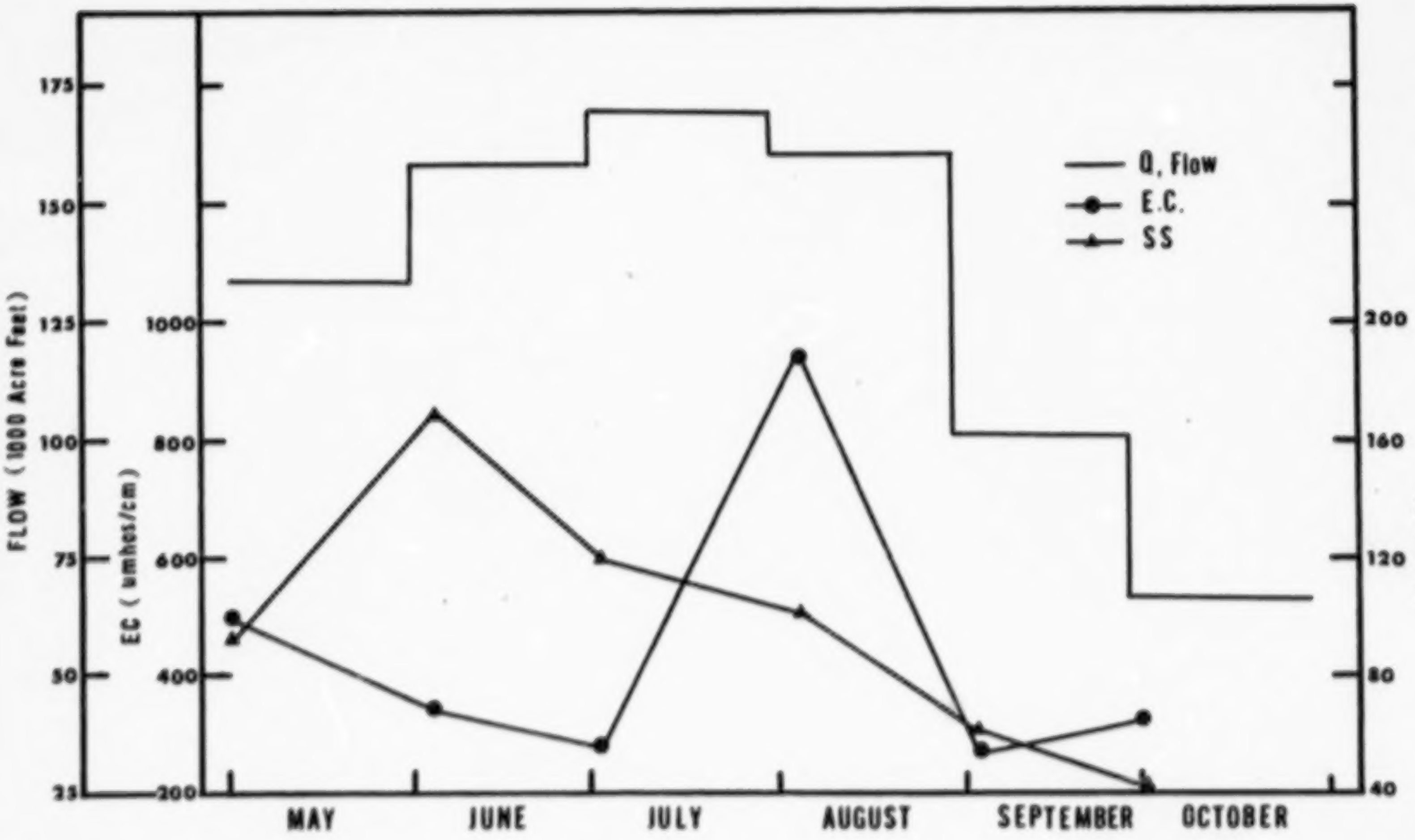

FIG.VII-2: FLOW, EC AND SS FOR SUPPLY STATION S-2
IN THE 1975 IRRIGATION SEASON.

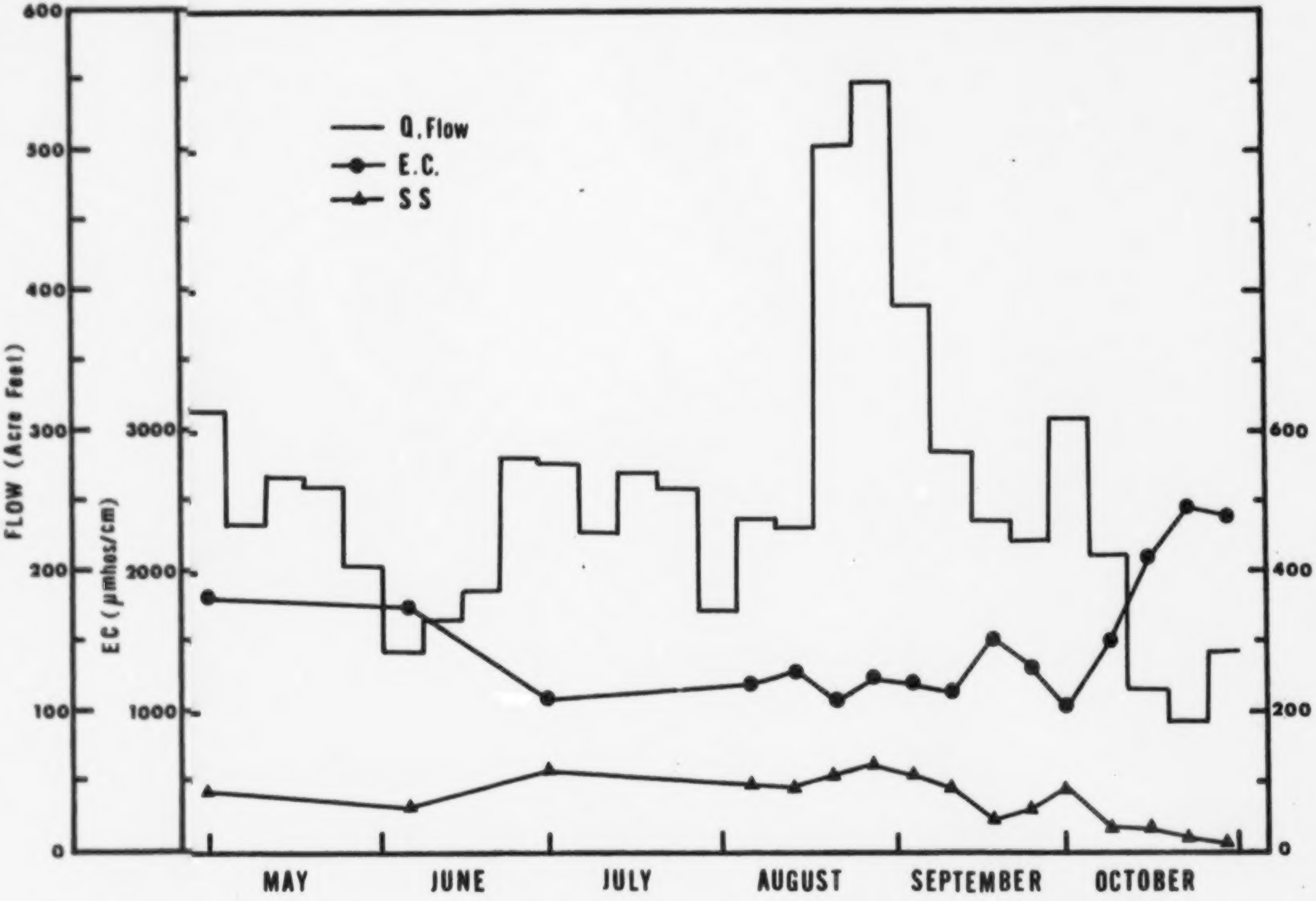

FIG. VII–3: FLOW, EC AND SS FOR DISCHARGE STATION D–1
IN THE 1975 IRRIGATION SEASON.

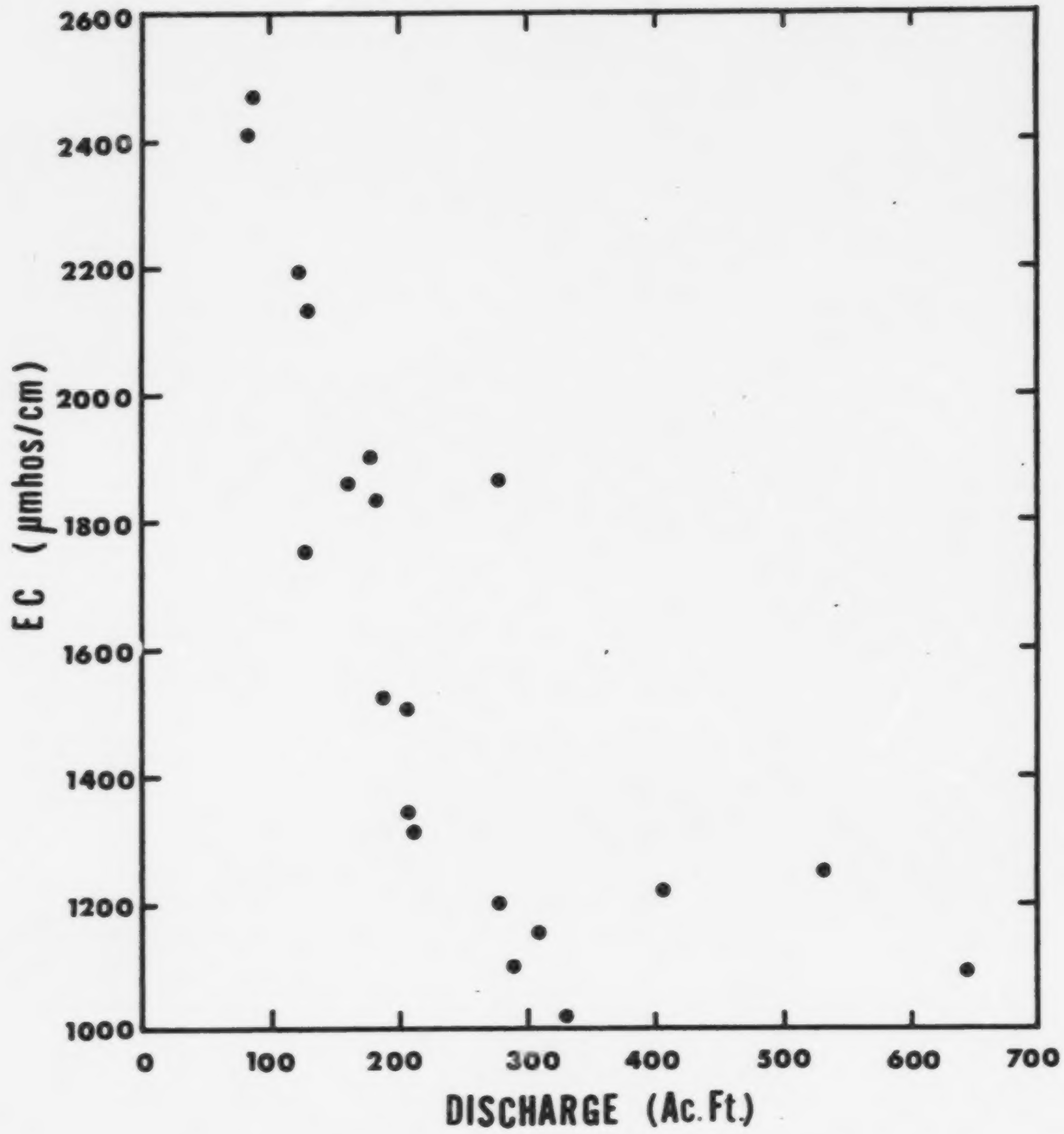

FIG. VII–4: RELATION BETWEEN EC AND DISCHARGE FOR STATION D-1 IN 1975.

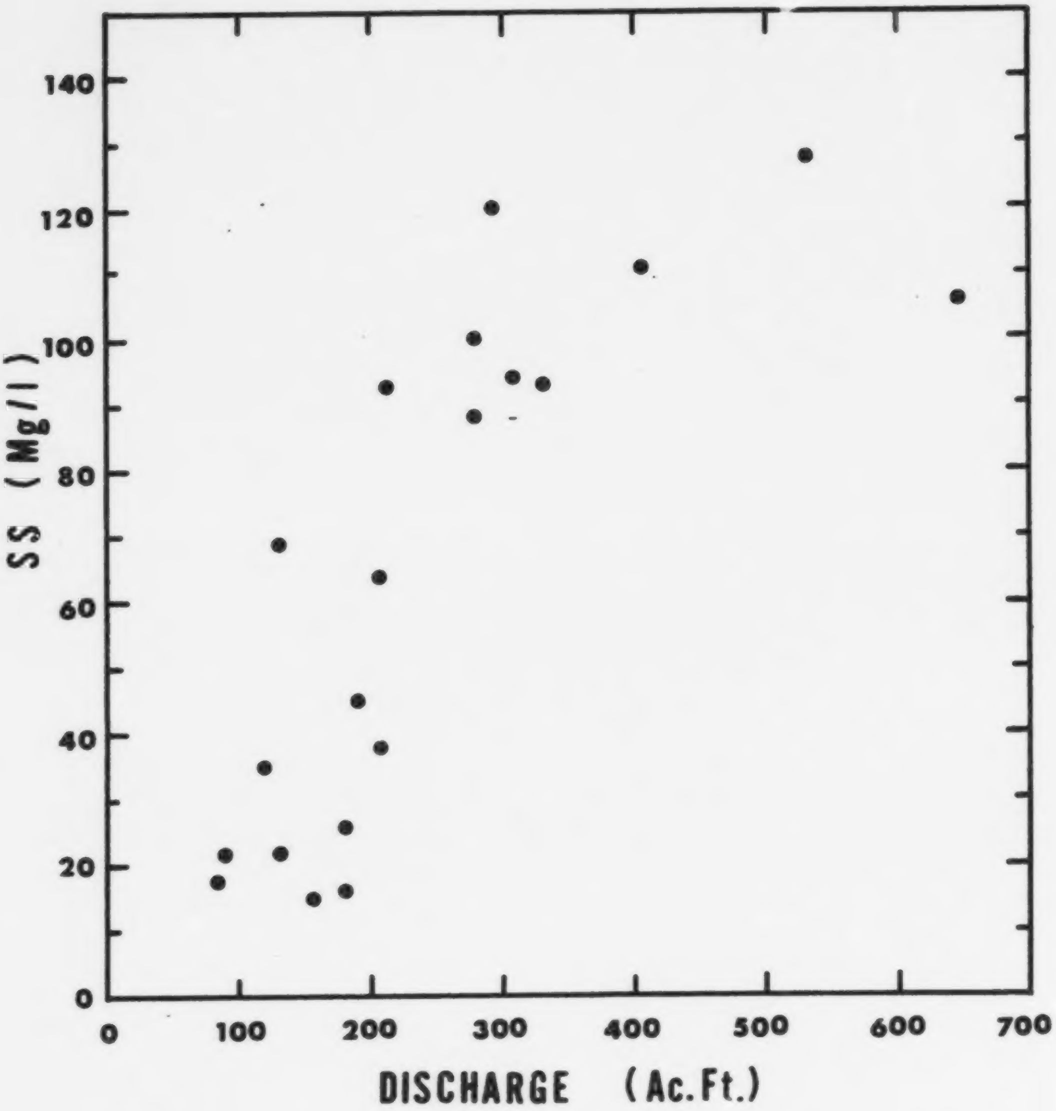

FIG. VII–5: RELATION BETWEEN SS AND DISCHARGE FOR STATION D–1 IN 1975.

water. Suspended solids increase with increasing flows, presumably due to higher average water velocities, which tend to keep sediments in suspension.

Figure VII-6 presents the relation between TDS and EC. EC is an intensive salinity parameter and is an electrical measurement of charged dissolved mineral salt species, while TDS is an extensive parameter and is a gravimetric measurement of dissolved inorganic and organic solids. In spite of these differences, the correlation coefficient (r) between EC and TDS was 0.99 for D-2. Figure VII-7 also presents the relationship between turbidity and SS. Turbidity is an intensive suspended matter parameter and is an optical measurement, while SS is an extensive parameter and is a gravimetric measurement. An r-value of 0.84 was obtained for D-2. Tables VII-2 and VII-3 summarize the above relations for the NPDES and EPA monitoring stations. Note that TDS is highly correlated with EC, but the y-intercept (a_o) and the slope (a_1) in the linear regressions are not similar, reflecting the variability in the chemical nature of these waters. Appendix Figure 2 contains a plot of TDS and EC for 288 different water samples from the Mendota-Crows Landing Return Flow Group, including district and on-farm measurements. An r-value of 0.994 was obtained with coefficients a_o and a_1 of -207.8 and 0.773, respectively. Table VII-3 indicates that turbidity and SS are not as well correlated as EC and TDS. However, most stations gave an r-value between 0.80 and 0.97.

Appendix Table 13 contains a detailed analysis of the dissolved mineral salts in the NPDES and EPA stations for the months of July through September of 1975. The imported supply water from the Sacramento Valley via the Delta is low in salts, and its composition reflects the geochemistry of the watershed but due to admixture in the Delta from various sources they are slightly higher in Na, Cl, and SO_4 concentrations than in the Sacramento River. The composition and concentration of the discharge waters are significantly different than the

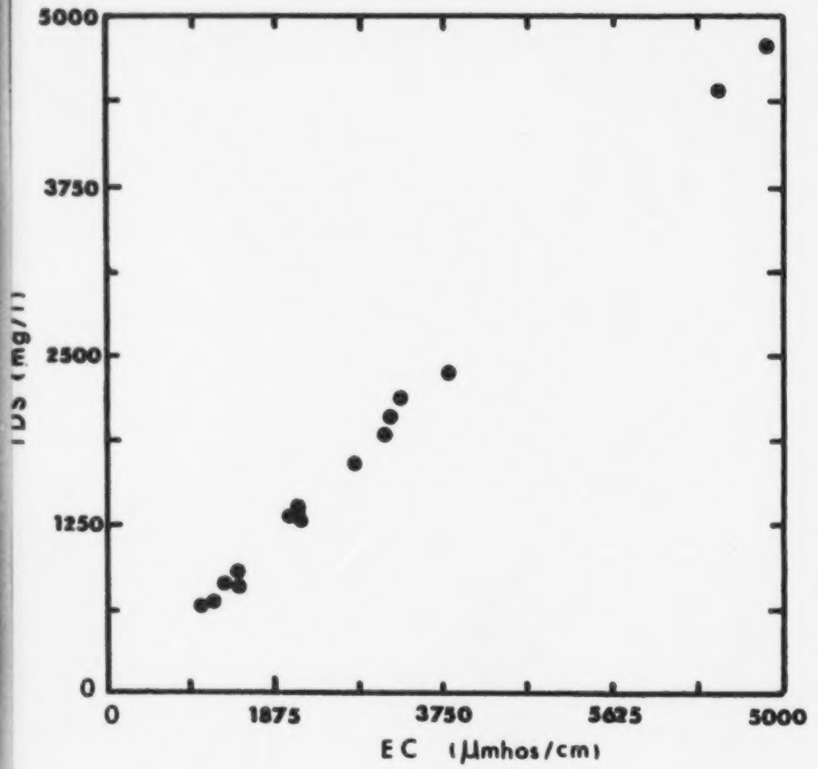

FIG. VII-6: RELATION BETWEEN TDS AND EC FOR STATION D-2 IN 1975.

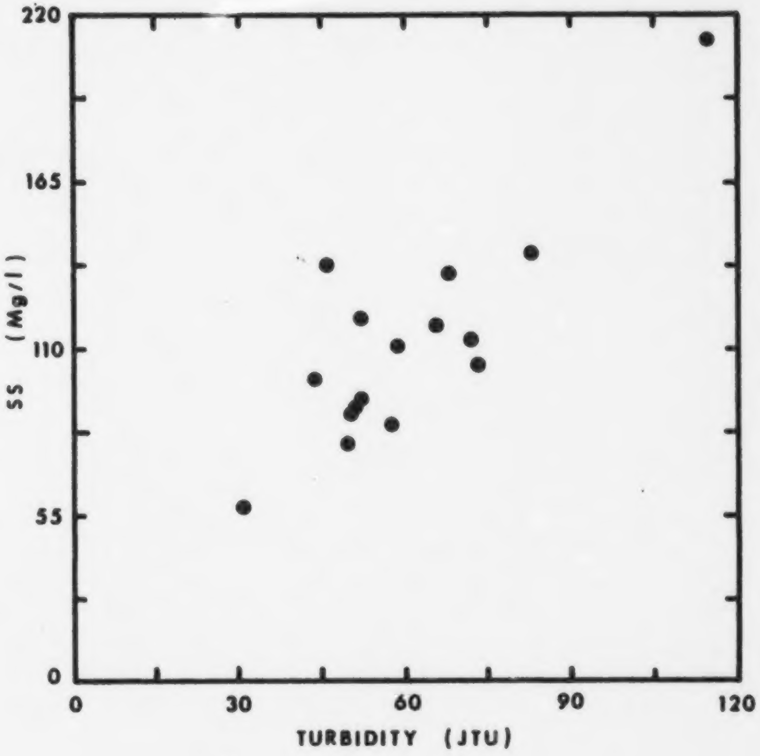

FIG. VII-7: RELATION BETWEEN SS AND TURBIDITY FOR STATION D-2 IN 1975.

Table VII-2: Relations between Total Dissolved Solids and Electrical Conductivity in the NPDES and EPA Monitoring Stations in the Mendota-Crows Landing Return Flow Group during the 1975 Irrigation Season.

Station	Range of Values		Coefficients for TDS = $a_o + a_1$ EC		Correlation Coefficient
	EC (μmhos/cm)	TDS (mg/ℓ)	a_o	a_1	r
S-1	395-631	239-375	-18.598	0.626	0.98
S-2	272-952	166-558	15.440	0.571	0.99
D-1	1,023-2,471	615-1,428	23.822	0.570	0.99
D-2	1,059-7,362	641-4,854	-84.972	0.674	0.99
D-3	442-1,236	251-750	-1.10	0.605	0.99
I-1	756-941	437-555	18.719	0.556	0.85
I-2	669-3,041	403-2,150	-149.43	0.713	0.99
I-3	2,298-3,387	1,359-2,109	-21.860	0.611	0.98
I-5	1,337-4,032	857-2,688	-117.669	0.705	0.99
I-6	2,537-4,012	1,622-2,903	-597.418	0.867	0.99
I-7	758-1,304	468-847	-77.604	0.697	0.99
I-8	667-1,932	349-1,098	2.017	0.568	0.99

Table VII-3: Relations between Turbidity and Suspended Solids in the NPDES and EPA Monitoring Stations in the Mendota-Crows Landing Return Flow Group during the 1975 Irrigation Season.

Station	Range of Values		Coefficients for SS = $a_o + a_1$ Turbidity		Correlation Coefficient
	Turbidity (JTU)	SS (mg/ℓ)	a_o	a_1	r
S-1	28-55	60-203	-0.681	2.634	0.55
S-2	30-55	44-168	-9.553	2.707	0.55
D-1	12-52	18-128	-5.665	2.509	0.92
D-2	31-115	58-212	19.71	1.518	0.84
D-3	6-870	5-3,844	55.55	1.576	0.97
I-1	17-50	17-92	-3.964	1.927	0.89
I-2	22-57	48-111	39.57	1.168	0.65
I-3	16-45	33-110	-10.63	2.605	0.87
I-5	42-180	112-530	21.62	3.122	0.93
I-6	67-220	175-615	-17.20	2.785	0.96
I-7	27-74	61-180	13.54	1.866	0.74
I-8	8-69	26-209	2.452	7.823	0.80

supply water. Salinity is higher, in particular Na, Cl and SO_4, due to the concentrating effects of evapotranspiration and salt pickup. This salt pickup occurs from the chemical weathering of the alluvial fill from the Coast Range, which is comprised of marine sedimentary rocks. Boron, another important elemental constituent of marine sedimentary rocks, is also high in concentration. For the September sampling, Total Nitrogen (the sum of organic and mineral N species) ranged between 0.6 to 3.4 mg/liter, except for I-5 and I-6, which had 5.2 and 13.4 mg/liter respectively. For these high-N return flows, the dominant N species was 4.3 and 12.6 mg/liter of nitrates, respectively. In other monitored stations, the organic-N and/or NO_3-N were the dominant species. It should be pointed out that the sources of N are manifold, including native soil N and fertilizer residues. BOD was about 0.6 mg/liter for most stations, except in areas draining wildlife and grassland habitats, where it ranged from 2.4 to 7.2 mg/liter. The higher BOD load is probably an indicator of animal (waterfowl, grazing animals, etc.) waste inputs into return flows.

B. Broadview Water District

Broadview Water District has a unique water management practice in that this district has been literally "drinking all of its water." This 10,000 acre district has not discharged any of its surface return flows since 1969. Broadview Water District captures at Station BWD-3, Figure VII-8, all of the surface return flows generated within their district and some surface inflows from contiguous irrigated tracts of land (BWD-1 and BWD-2). All of these return flows are pumped into the district main supply canal near BWD-3 and mixed with freshwater from the Delta-Mendota Canal obtained at BWD-5. Station BWD-4 characterizes the mixed supply water delivered to growers.

Table VII-4 points out that Broadview Water District diverted 13,795 ac-ft of water from the Delta-Mendota Canal and delivered 26,894 ac-ft to growers.

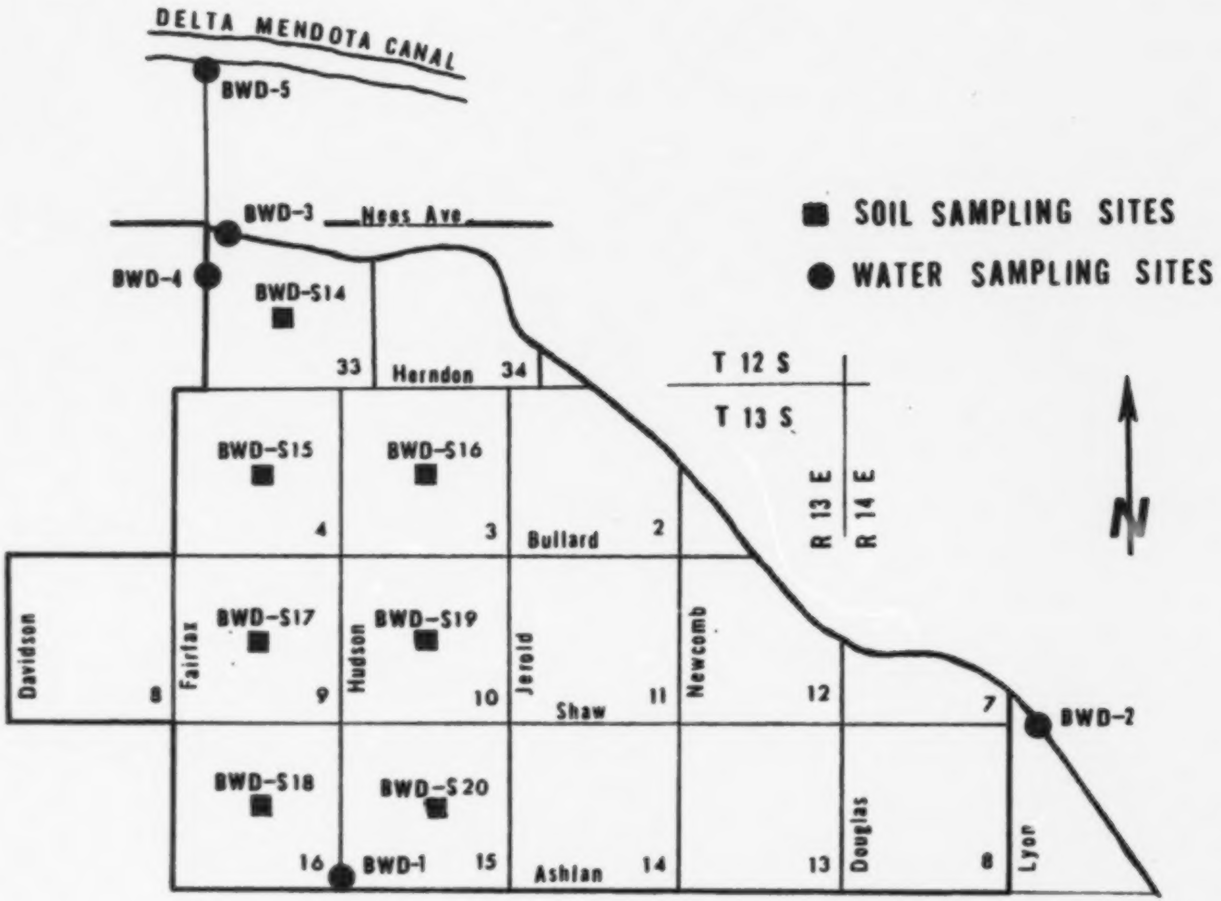
DELTA MENDOTA CANAL
BWD-5
BWD-3
Ness Ave.
BWD-4
BWD-S14
33
Herndon
34
■ SOIL SAMPLING SITES
● WATER SAMPLING SITES
T 12 S
T 13 S
R 13 E
R 14 E
N
BWD-S15
BWD-S16
4
3
Bullard
2
Davidson
8
Fairfax
BWD-S17
9
Hudson
BWD-S19
10
Jerold
Shaw
11
Newcomb
12
7
BWD-2
BWD-S18
BWD-S20
16
BWD-1
15
Ashlan
14
13
Douglas
8
Lyon

FIG.VII-8: BROADVIEW WATER DISTRICT SOIL AND WATER SAMPLING SITES

Table VII-4: Blend of Fresh and Return Flow Waters for Broadview Water District in the 1975 Irrigation Season.

Month	BWD-5		BWD-3		BWD-4			
	Q	EC	Q	EC	Q	EC	FWA EC	% Difference
March	3,220	-	1,998	-	5,218	-	-	-
April	1,252	-	1,616	-	2,868	-	-	-
May	1,265	555	1,539	4,435	2,804	3,400	2,685	-21
June	2,881	446	3,043	2,117	5,924	1,037	1,304	+26
July	2,670	729	2,506	2,040	5,176	1,546	1,364	-12
August	1,132	600	1,357	1,923	2,489	1,067	1,321	+24
September	345	259	410	1,846	755	708	1,121	+58
October	1,030	411	630	3,259	1,660	1,410	1,492	+6
TOTAL	13,795	-	13,099	-	26,894	-	-	-

BWD-5 = Delta-Mendota Canal fresh water

BWD-3 = Captured drain water

BWD-4 = Delivered supply water containing fresh and drain water

Q = Water flow in ac-ft; Q for BWD-3 is difference between Q for BWD-4 and BWD-5

EC = Measured electrical conductivity in micromhos/cm

FWA EC = Calculated flow-weighted average EC

% Difference = Difference between measured EC and FWA EC

The difference between these two quantities, 13,099 ac-ft, represents an estimate of drain water captured during the 1975 irrigation season. Thus, the water delivered to growers is about a 50-50 mixture of fresh and drain waters. The average water application rate is estimated to be 2.90 ft (ac-ft/ac of cropland).

All of the EC's reported in Table VII-4 are measured values while the FWA EC is the calculated flow-weighted average EC. With the exception of the month of September, a comparison between the calculated FWA EC and the measured EC ranges from -21% + 26%. These differences are considered to be reasonable since measured EC's are obtained only once a month, and there are some errors in estimating Q's. The FWA EC was computed to confirm the blend of half-and-a-half supply water, based on quantity estimates.

Table VII-5 presents the average seasonal water quality from monthly data reported in Appendix Table 15. The diverted canal water at BDW-5 is of good quality, but when blended with captured drain water (BWD-3), the mixed supply water at BWD-4 was considerably degraded in salinity and boron contents. Stations BWD-1 and BWD-2 are rim inflows from upslope irrigated lands. The latter is of poorer quality than the former; probably indicative of the presence of some collected subsurface drainage. Attempts to measure rim inflows were not successful during the 1975 irrigation season. However, structural modifications have been made to obtain flows in the future.

Table VII-6 gives estimates on seasonal mass transfers of TDS and SS. Column 3 contains the calculated difference between measured quantities found in delivered and diverted waters. This calculated difference should represent the mass of salts and sediments in the captured drain water. However, the calculated difference was found to be 8% larger for TDS and 22% smaller for SS than the measured masses in the captured drain water. These discrepancies may be partly attributed to the analysis presented in Table VII-4. Nevertheless, Table VII-6

Table VII-5: Seasonal Water Quality Data for Broadview Water District during the 1975 Irrigation Season.

Station	Description	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)
BWD-5*	Diverted canal water	550	314	38	129	0.16
BWD-3*	Captured drain water	2,506	1,646	153	449	1.84
BWD-4*	Delivered mixed supply water	1,553	1,028	78	237	0.90
BWD-1†	Contiguous surface inflow	639	358	116	292	0.31
BWD-2†	Contiguous surface inflow	1,316	835	102	279	0.69

* flow-weighted average

† not flow-weighted

Table VII-6: Estimated Seasonal Mass Transfers of Salts and Sediments in Broadview Water District during the 1975 Irrigation Season.

	Delivered water (BWD-4)	Diverted canal water (BWD-5)	Calculated* difference	Captured drain water (BWD-3)
TDS, tons/season	37,600	5,891	31,709	29,323
TDS, lbs/ac†	7,929	1,242	6,687	6,184
SS, tons/season	8,668	2,420	6,248	7,999
SS, lbs/ac†	1,828	510	1,318	1,687

* (BWD-4) - (BWD-5)

† based on 9,484 net acres of irrigated and nonirrigated lands

points out that salts contained in the applied Delta-Mendota Canal water contributed nearly 3/4 ton per acre, whereas the captured drain water contributed nearly 3 tons per acre. A similar analysis was made for suspended solids. The sediment brought into the district with the canal diversion was about 510 lbs per acre while captured drain water recirculated about 3/4 ton per acre.

Table VII-7 contains a summary of soil salinity and soil boron data for seven sampling sites (Fig. VII-8). The data for individual sampling sites are found in Appendix Table 17. These sampling sites were sampled to the water table from 5 to 13 feet beneath the land surface. The Panoche soil series is predominant in this area, with textures ranging from loam to clay. The surface 1/2-ft depth was salt-affected with EC_e (EC of saturation extract) ranging from 4 to 16 millimhos/cm, except for one site which had an EC_e of 2.3 mmhos/cm. Estimates of total soluble salts in tons per ac-ft of soil were made from EC_e and saturation percentage, the reference soil-water content used to extract the soil solution in the laboratory. Gypsum, $CaSO_4 \cdot 2H_2O$, was also measured. It is a naturally occurring mineral that contributes to soil salinity. Gypsum was exceedingly high only in two out of seven sites (BWD S14 and BWD S15 in Fig. VII-8), therefore, the average gypsum data in Table VII-7 is misleading. The average boron data, however, was more representative of the seven sites.

Appendix Table 16 gives the detailed analyses on dissolved salt constituents for the water sampling stations. The captured drain water was moderately saline, containing largely Na, Cl, and SO_4. The mix of freshwater and drain water delivered to growers also contained the above mentioned three ions as the dominant ones. A one-time analysis for nitrogen in these waters showed Total Nitrogen ranging from 10.2 mg/liter in the drain water (BWD-3), 1.1 mg/liter in the diverted canal water (BWD-5), and 4.4 mg/l for the mixed supply water (BWD-4). The dominant N species were NO_3-N and Organic N. BOD ranged from 0.6 to 4.2 mg/liter.

Table VII-7:

Summary of Soil Data (average values) - Broadview Water District

1975

Depth (ft.)	EC_e* (mmhos/cm)	Estimated soluble salts† (tons/ac-ft soil)	Gypsum† (tons/ac-ft soil)	Boron (mg/ℓ)
0-½	7.48	5.61	2.97	1.84
½-1	4.13	3.62	6.80	1.29
1-1½	3.37	2.84	14.76	1.11
1½-2	3.11	2.81	0.73	1.00
2-3	3.23	2.92	0.38	1.23
3-4	3.18	2.88	11.10	1.21
4-5	3.27	2.40	11.33	1.33
5-6	3.54	2.70	7.01	1.31
6-7	4.36	3.36	5.54	1.87
7-8	3.04	2.47	6.41	1.13
8-9	2.94	2.57	4.35	1.22
9-10	2.81	2.41	0.56	0.82
10-11	2.16	1.79	0.34	0.96
11-12	1.24	0.73	0.41	0.88
12-13	1.31	0.77	0.34	0.95

* EC_e is EC of soil saturation extract.

† Based on ac-ft of soil. Profile depth increments should be considered when calculating mass of salts or gypsum.

Table VII-8 contains the 1975 cropping pattern and average yeild. Tomatoes, cotton, and barley were the major crops grown during the 1975 irrigation season. In spite of the comparatively poor supply water quality due to the reuse of surface return flows, the salinity in the surface soil and the crop yields appear to be unaffected. How long this trend will persist is not known.

C. Panoche Water District

The 44,000 acre Panoche Water District, Figure VII-9, was another entity studied in the Mendota-Crows Landing Return Flow Group. In contrast to Broadview Water District, this district does have a surface discharge outlet. Some of the drain water produced in the Panoche Water District is reused at the field and farm sites, and some is pumped into the supply canal of a neighboring irrigation district. But most of the drain water from the district is discharged through Panoche Drain (I-6) into the grassland and wildlife habitats, where extensive reuse occurs.

In addition to district-wide assessments, on-farm studies were conducted in a 170 acre tomato field and on a 1,675 acre tile-drained farm, indicated by the shaded portions in Figure VII-9. A U.S. Weather Bureau Class A evaporation pan was also installed in an irrigated pasture near the Panoche Water District office, to obtain estimates on potential evapotranspiration rates for this study area.

Panoche Water District is one of four entities in the Panoche Drainage District. The other three entities are the Ora Loma Water District, the Eagle Field Water District, and part of the Mercy Springs Water District located in the vicinity of the Delta-Mendota Canal and the Outside Canal (Fig. VII-9). Irrigation return flows from all of these four entities are discharged into Panoche Drain.

Table VII-8: Crop and Yield Report for the Broadview Water District during the 1975 Irrigation Season.

Crop	Acres Harvested	Average Yield per Acre
Cotton	2,673	2.53 bales
Barley	2,547	2.47 tons
Alfalfa Seed	1,094	754.4 pounds
Melons (double crop)	310	211.7 cartons
Tomato	2,976	27.1 tons
Sugar Beets	411	32.3 tons
Wheat	766	2.31 tons
TOTAL	9,262	

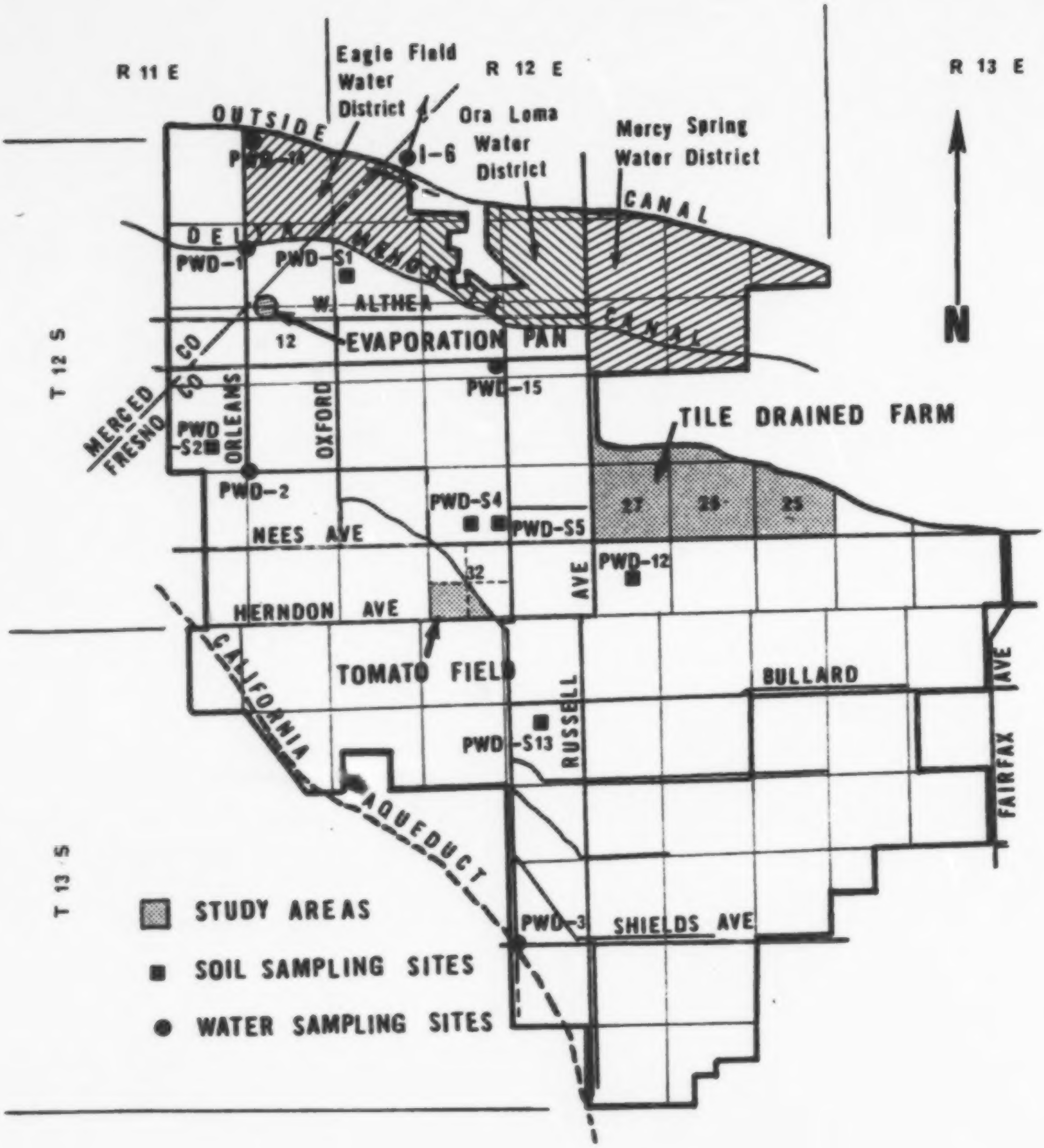
R 11 E
R 12 E
R 13 E
Eagle Field Water District
Ora Loma Water District
Mercy Spring Water District
OUTSIDE CANAL
DELTA MENDOTA CANAL
PWD-1A
I-6
PWD-1
PWD-S1
W. ALTHEA
12
EVAPORATION PAN
PWD-15
T 12 S
T 13 S
MERCED CO
FRESNO CO
PWD -S2
ORLEANS
OXFORD
PWD-2
TILE DRAINED FARM
27
26
25
PWD-S4
PWD-S5
NEES AVE
32
PWD-12
AVE
HERNDON AVE
CALIFORNIA AQUEDUCT
TOMATO FIELD
RUSSELL
BULLARD
AVE
FAIRFAX
PWD-S13
PWD-3
SHIELDS AVE
N
▨ STUDY AREAS
■ SOIL SAMPLING SITES
● WATER SAMPLING SITES

FIG.VII-9: PANOCHE WATER DISTRICT STUDY AREAS, SOIL AND WATER SAMPLING SITES.

Table VII-9 presents data on water inflows and outflows, and analyses of their relationships for the period January through October of 1975 in the Panoche Drainage District. Panoche Water District has two sources of imported waters, the Delta-Mendota Canal and the California Aqueduct. The quantities of purchased and delivered water are reported, and if the difference between them is positive, this gives an estimate of captured return flow; if the difference is negative, this gives an estimate of seepage and other losses. For 1975 the net captured return flow was estimated at 1,455 ac-ft, or 1.3% of the total purchased water, for Panoche Water District.

A similar analysis is not available for the other three water districts. Eagle Field, Mercy Springs, and Ora Loma Water Districts obtain their supply water from the Delta-Mendota Canal and some from the Outside Canal. The total supply water for all entities in the Panoche Drainage District was 128,749 ac-ft.

With regards to the discharge of surface return flows, approximately 17% was pumped directly into the supply canal for CCID, while the remainder was discharged into the Panoche Drain (I-6). An analysis of supply-discharge relations gives a surface drainage index of 0.31; i.e., surface drainage is 31% of Panoche Drainage District's supply water, in contrast to 0% for the Broadview Water District. The unit applied water in Panoche Drainage District is estimated to be 3.23 ft as compared to Broadview Water District's 2.90 ft, while the unit surface drainage is estimated to be 0.91 ft in the former district.

Table VII-10 gives the seasonal flow and water quality for Panoche Water District during the 1975 monitored irrigation season from May through October, which summarizes the data presented in Appendix Tables 20 and also 24 for PWD-13E. The district supply waters are of good quality. Suspended matter

Table VII-9: Supply and Discharge Waters (in acre-feet) for the Panoche Drainage District during the Period January through October, 1975.

Supply Water	Purchased Water	Delivered Water	Recaptured Water
Delta-Mendota Canal Water	66,583	75,796	5,746
California Aqueduct Water	41,859	37,915	-4,291
Subtotal for Panoche Water District	108,442	113,711	1,455
Other Districts* Delta-Mendota Canal Water and Outside Canal	20,307		
Total Supply	128,749		

Discharge Water	Discharge Water
Panoche Drain (I-6)	32,723
Captured by Central California Irrigation District	6,904
	39,627

Supply-Discharge Relations:

Surface Drainage Index = Discharge/Supply = 39,627/128,749 = 0.31

Unit Applied Water = Supply/Irrigated Acres = 128,749/39,922 = 3.23 ac-ft/ac

Unit Surface Drainage = Discharge/Net Acres = 39,627/43,762 = 0.91 ac-ft/ac

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* Mercy Springs W. D. = 2,272 ac; 9,648 ac-ft
Ora Loma W. D. = 1,180 ac; 5,702 ac-ft
Eagle Field W. D. = 1,400 ac; 4,957 ac-ft

Table VII-10: The 1975 Monitored (May through October) Seasonal Flow and Quality in the Panoche Water District.

Station	Description	Q (ac-ft)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)
Supply Stations:							
PWD-1	Delta-Mendota Canal Water	44,017*	353	211	38	102	0.16
PWD-3	California Aqueduct Water	23,096*	423	236	12	19	0.17
Discharge Station:							
I-6	Panoche Drain †	19,458 *	3,070	2,053	126	348	4.82
Internal Stations:							
PWD-2	Supply Canal at Lift #4	24,894	580	331	41	120	0.33
PWD-13E	Hammond Drain	—	2,840	1,518	586	1,614	3.00

* see Table VII-9 for Total Q for January through October, 1975.

† includes discharge from Eagle Field, Mercy Springs, and Ora Loma Water Districts.

is lower in the California Aqueduct, probably due to impoundment in the San Luis Reservoir and conveyance in the concrete-lined canal system. The district return flow in Panoche Drain was about eight times more saline than the supply water. Such a large increase in salinity can only be attributed to the leaching of native salts present in the soils. In addition, boron and suspended matter in the discharge water are very high when compared to the supply water. All of these observations are a reflection of the chemical and physical properties in the area; i.e., the soils are salt-affected and highly susceptible to erosion. Two other stations (PWD-2 and PWD-13E) were sampled and these represent internal points in the Panoche Water District. PWD-2 is on the supply canal which conveys Delta-Mendota Canal Water from PWD-1 by a series of lift pumps. Some admixture of return flows takes place as the freshwater is lifted. This observation is supported by the slight increases in salinity indicated by EC and TDS and boron. PWD-13E is located on Hammond Drain, shown on the map of the tile-drained farm (Fig. VII-10). The quality of this return flow is similar but higher in SS than that found in the Panoche Drain which is located farther downstream in the drainage network.

Appendix Table 21 contains additional water quality data for these district and on-farm stations in the Panoche Water District for June and September, 1975. Evidences for the water being lifted from PWD-1 to PWD-2 as receiving return flow inputs are noted by increases in Na, Ca, Cl, SO_4, Total N and NO_3-N. The water samples obtained from PWD-13E for detailed analyses inadvertently were for the months in which drain waters were least saline (Appendix Table 20). Nevertheless, substantial pickup in almost all constituents is noted when comparing PWD-13E to either PWD-1 or PWD-3. It is of interest to note that Total N at PWD-13E in September was 10.8 mg/liter, with 8.6 mg/liter of N in the NO_3-N form. BOD results were similar, 0.6 mg/liter, to that found in Broadview Water District's return flows.

Table VII-11 presents the average of all soil data obtained in Panoche Water District, including the on-farm soil samples. Data for 13 soil sampling sites are found in Appendix Table 23, and sampling sites are noted in Figures VII-9, VII-10, and VII-11. When comparing this average data with the average for Broadview Water District, it is noted that the surface soils are less saline in Panoche than in Broadview Water District. At deeper soil depths, however, the reverse is true. In Panoche Water District, gypsum is present in significant quantities in the 7-9 ft depths only, while it is present as stratified layers in several locations in the soil profiles of Broadview Water District. Boron is much higher in Panoche Water District below the 1 1/2-ft soil depth than in Broadview. Closer examination of Appendix Table 23 shows that some sampling sites were relatively salt-free, while others were highly salt-affected. The Cl data gives an indication of the leaching patterns in these sites since it is assumed to be non-reactive with regards to ion exchange and mineral dissolution, or precipitation.

Table VII-12 contains a crop and yield report. Unlike Broadview Water District, cotton, tomatoes and melons are the major crops in Panoche Water District. The crops are more diverse in number, with a small acreage of tree crops. As in Broadview Water District, in spite of the presence of salt-affected soils and some reuse of saline and boron-containing return flows, the crop yields were not greatly affected.

Tile-Drained Farm

Figure VII-10 contains a map of the 1,675 acre tile-drained farm studied in the Panoche Water District. With the assistance of the Soil Conservation Service, the grower started developing a subsurface drainage system in the fall of 1968. Plans called for an eventual 1,100 acres to be tile-drained, starting with the first 670-acre tract in the eastern portion of the farm.

Table VII-11:

Summary of Soil Data (average values) - Panoche Water District

1975

Depth (ft.)	EC_e* (mmhos/cm)	Estimated soluble salts (tons/ac-ft soil)	Gypsum (tons/ac-ft soil)	Boron (mg/ℓ)
0-½	1.60	1.08	0.38	0.99
½-1	1.51	1.06	0.37	1.15
1-1½	1.73	1.33	0.43	1.48
1½-2	2.05	1.51	0.53	2.05
2-3	2.80	2.13	0.65	2.80
3-4	3.61	2.78	3.76	3.53
4-5	3.96	3.08	2.60	3.57
5-6	4.17	3.31	5.09	3.50
6-7	3.78	3.10	4.97	3.16
7-8	4.04	4.10	19.90	3.27
8-9	3.64	3.47	14.28	3.83
9-10	1.02	0.59	0.40	1.90

* EC_e is EC of soil saturation extract.

Table VII-12:

Crop Report for Panoche Water District

Mendota-Crows Landing Return Flow Group

1975

Crop	Acres Harvested	Average Yield per Acre
Almonds	118	641 lbs
Alfalfa Hay	472	10,485 lbs
Alfalfa Seed	886	510 lbs
Barley	1,483	49 sacks
Cotton	11,004	1.96 bales
Garlic	344	6.2 tons
Lettuce	862	674 cartons
Sugar Beets	1,069	28 tons
Pasture	1,236	
Wheat	2,923	2.7 tons
Safflower	1,617	25.0 cwt.
Tomatoes	7,506	29 tons
Corn	750	20.4 tons
Oats	450	9.6 tons
Cantaloupes	3,728	312 crates
Crenshaws	240	800 crates
Honeydew	135	625 crates
Prunes	127	4.44 tons
Vegetable Seeds	120	6.5 lbs
TOTAL	35,070	

Area not harvested	37 acres
Area double cropped	620 acres
Area in fallow	130 acres
Area non-cropped	1,185 acres
Water other than project water	208 acres

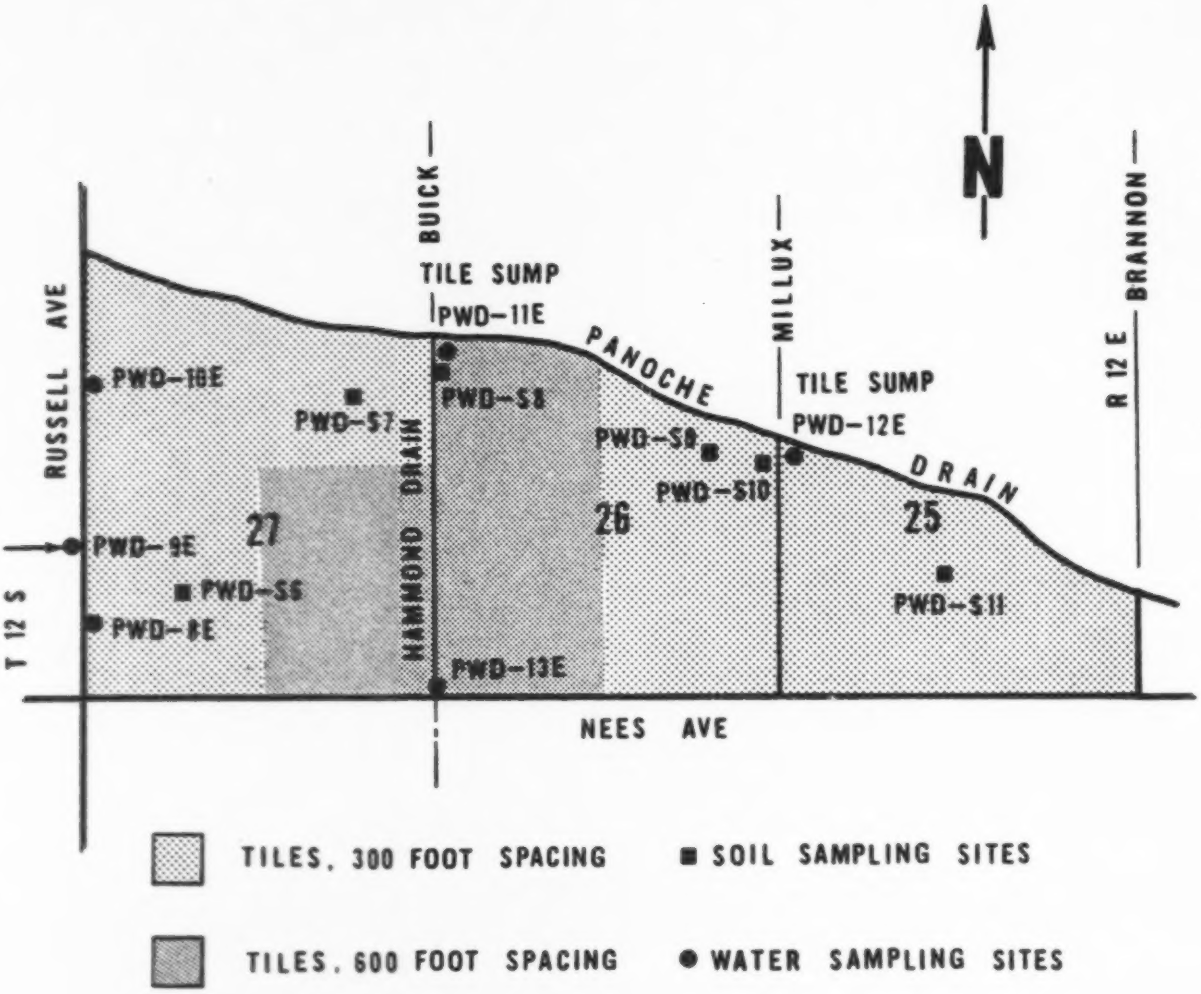

N
BUICK
MILLUX
BRANNON
RUSSELL AVE
TILE SUMP
PWD-11E
PANOCHE DRAIN
TILE SUMP
PWD-12E
R 12 E
PWD-10E
PWD-S7
PWD-S8
PWD-S9
PWD-S10
HAMMOND DRAIN
27
26
25
PWD-9E
PWD-S6
PWD-8E
T 12 S
PWD-13E
PWD-S11
NEES AVE
TILES, 300 FOOT SPACING
TILES, 600 FOOT SPACING
SOIL SAMPLING SITES
WATER SAMPLING SITES

FIG. VII–10: TILE DRAINED FARM IN PANOCHE WATER DISTRICT. SOIL AND WATER SAMPLING SITES.

For this first 670 acres, about 61,700 lineal ft of 6-12" concrete tile was installed at 600 ft lateral spacing and at a 7 ft soil depth, and then backfilled with a sand-gravel mix. It had a design capacity of 2.61 cfs. The tile effluents were collected in a sump at PWD-12E. Since then, the work plans for subsurface drainage have been progressing steadily. In 1971, however, the grower made a change from the original design, substituting 4" corrugated plastic for the 6" concrete laterals. Recommended spacings were from 240-300 ft, but the grower used 600 ft spacing, with the intention of adding another lateral between the 600 ft spacing after a hydraulic check. More recently, 8" corrugated plastic lines are being installed instead of 10" concrete baseline tile. Figure VII-10 shows the extent of tile drainage to date and the lateral spacings.

Tile effluents are collected in two sumps, at PWD-12E and PWD-11E, and discharged into the Panoche Drain. This drainage water, which includes collected surface and subsurface waters from this farm and others upslope, flows in a northeasterly direction and some of it is captured at PWD-10E, mixed with freshwater from PWD-9E, and then used for irrigation in the tile-drained farm. Station PWD-8E represents the mixed supply water. In addition, minor amounts of drain water are also pumped from Hammond Drain at PWD-13E and reused.

Table VII-13 gives water flow data for the calendar year 1975. The freshwater supply consisted of 3,648 ac-ft, which was mixed with more than 1,870 ac-ft of drain water. From late May through December, another 19 ac-ft was reused from Hammond Drain. The tile sumps discharged about 291 ac-ft during the monitored period.

Table VII-14 presents the flow and flow-weighted quality data for the monitoring period encompassing May through October of 1975. The Delta-Mendota

Table VII-13: 1975 Calendar Year Water Flows in Acre-Feet for the Tile-Drained Farm in Panoche Water District.

Month	PWD-9E fresh water	PWD-10E captured drain water	PWD-8E mixed supply water	PWD-11E tile drainage effluent	PWD-12E tile drainage effluent	PWD-13E Hammond Drain
Jan.	0					
Feb.	327					
Mar.	355					
Apr.	182					
May	225	200*		6*	6*	0
June	546	703	1,249	15	24	0
July	315	675	990	16	25	14
Aug.	35	194	229	13	13	2
Sept.	4	0	4	5	9	1
Oct.	1,219	65	1,284	17	6	2
Nov.	440	33	473	13	14	0
Dec.	0	0	0	21	8	0
Total	3,648	1,870†	4,229†	106†	185†	19†

* 1 week of measurement in May

† totals represent only monitored period; estimates not available between January and May

Table VII-14: Seasonal Water Flow and Quality for the Period May through October, 1975 in the Tile-Drained Farm.

Stations	Description	Q (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)
PWD-9E	Fresh Water	2,344	268	206	24	54	0.21
PWD-10E	Captured Drain Water	1,837	1,963	1,266	59	139	2.36
PWD-8E	Mixed Supply Water	4,181	1,386	880	38	58	1.30
PWD-11E	Tile Effluent	72	11,588	8,897	5	24	23.0
PWD-12E	Tile Effluent	163	8,540	6,713	1	7	9.04
PWD-13E	Hammond Drain	19	2,840	1,518	586	1,614	3.00

Canal water at PWD-9E was of good quality. The drain water captured at PWD-10E was saline, (nearly 2,000 μmhos/cm), and contained 2.4 mg/ℓ of boron. The resultant mixed supply water had an average EC of nearly 1,400 μmhos/cm, and 1.30 mg/ℓ boron. Based on our monitored quantity data, it appears that the supply water was a blend of 44:56 of fresh and captured drain waters. As expected the tile effluents collected at PWD-11E and PWD-12E were extremely saline (between 8,500 and 11,600 μmhos/cm) high in boron (between 9 and 23 mg/ℓ), and low in suspended matter. Hammond Drain at PWD-13E has been discussed previously, but note its salinity, boron, and SS concentrations. Based upon the data presented in Table VII-14, 657 tons of salts were brought in with the fresh supply water, and 4,904 tons of salts were recirculated with the captured drain water.

The locations of six soil sampling sites are found in Figure VII-10, and the data are reported in Appendix Table 23. A summary of the soil data is given in Table VII-15 as average values. Throughout the profile the soils are moderately saline and boron-affected. Except for the top 2 ft of soil, gypsum is present throughout, in significant amounts. A closer examination of individual sampling sites indicates that only sites PWD-S6 and PWD-S11 are relatively unaffected by salts and boron. The Cl concentrations are low throughout the profile, indicating substantial leaching. All other sites contained appreciable salinity, with sites PWD-S9 and PWD-S10 in the close vicinity of PWD-12E being the most salt-affected. EC_e ranged up to about 15 mmhos/cm, and boron up to 59 mg/ℓ. As noted earlier in Table VII-14, the effluents from this farm were of extremely poor quality.

Table VII-16 indicates the crops grown in 1975 and their yields, which compared favorably with the district yields (Table VII-12).

Table VII-15:

Summary of Soil Data (average values) from Tile Drained Field in Panoche Water District

1975

Depth (ft.)	EC_e* (mmhos/cm)	Estimated soluble salts (tons/ac-ft soil)	Gypsum (tons/ac-ft soil)	Boron (mg/ℓ)
0-½	3.55	3.30	2.06	2.81
½-1	3.75	3.48	2.68	2.83
1-1½	4.11	4.25	1.07	2.53
1½-2	4.75	5.11	1.55	2.78
2-3	6.35	7.10	13.54	3.75
3-4	6.72	7.03	21.04	4.27
4-5	6.97	7.34	21.63	4.38
5-6	7.42	8.35	12.26	5.17
6-7	7.55	8.96	11.15	5.83
7-8	8.37	8.85	14.30	7.35
8-9	4.44	4.57	8.76	3.37
9-10	4.74	5.69	7.45	3.95
10-11	5.39	6.19	12.12	4.62
11-12	4.12	3.16	0.58	5.40

* EC_e is EC of soil saturation extract.

Table VII-16:

Crop Report for Tile Drained Farm in Panoche Water District

Mendota-Crows Landing Return Flow Group

1975

Crop	Acres Harvested	Average Yield per Acre
Wheat	640	2.9 tons
Cotton	320	2.3 bales
Tomatoes	710	2.5 tons
TOTAL	1,670	

Furrow-Irrigated Tomato Field

Figure VII-11 gives a layout of the 170-acre tomato field in Panoche Water District, which was monitored for tailwater production and recovery. The supply water was obtained from the California Aqueduct through PWD-4T and from the Delta-Mendota Canal at PWD-6T. This 170-acre field was divided into three subfields for cultural operations. The arrows show the direction of water flow for the farm distribution system, the application of water into furrows, and the collection and reuse of return flows. Station PWD-7T is located on the return flow sump. All of the tailwater produced was reused in Subfields II and III.

Table VII-17 contains the results of a test made between July 12-17, 1975, in the 156 acres of Subfields I and II. During this test period the irrigator applied 28.54 ac-ft of water on 156 acres, or 2.20 surface inches. The amount of tailwater produced was 8.21 ac-ft, or 0.63 surface inches. In other words, runoff comprised of 28.7% of the applied water, as measured by a line meter installed at the sump pump.

During this same test period, on July 16, 1975, a more direct measurement was carried out in Subfield I. There were 36 check dams in the supply ditch for Subfield I. Typically, irrigation water was diverted into 55-65 furrows (4 to 6 checks) at a time, using 2-3 siphons (of 1 1/2" diameter) per furrow. The water was applied for about a 6-8 hour duration per 1,000 ft run. Table VII-18 gives the results for a 9.6 acre portion of the 77.6 acre Subfield I, which had 63 furrows between checks 27-32 (shaded area in Fig. VII-11). The average amount of water applied was 3.75 surface inches, greater than the average given in Table VII-17, and runoff was 0.90 surface inches, or 24% of the water applied. On-site measurements for EC and turbidity were determined with a HACH DR-EL portable meter. The EC field measurements

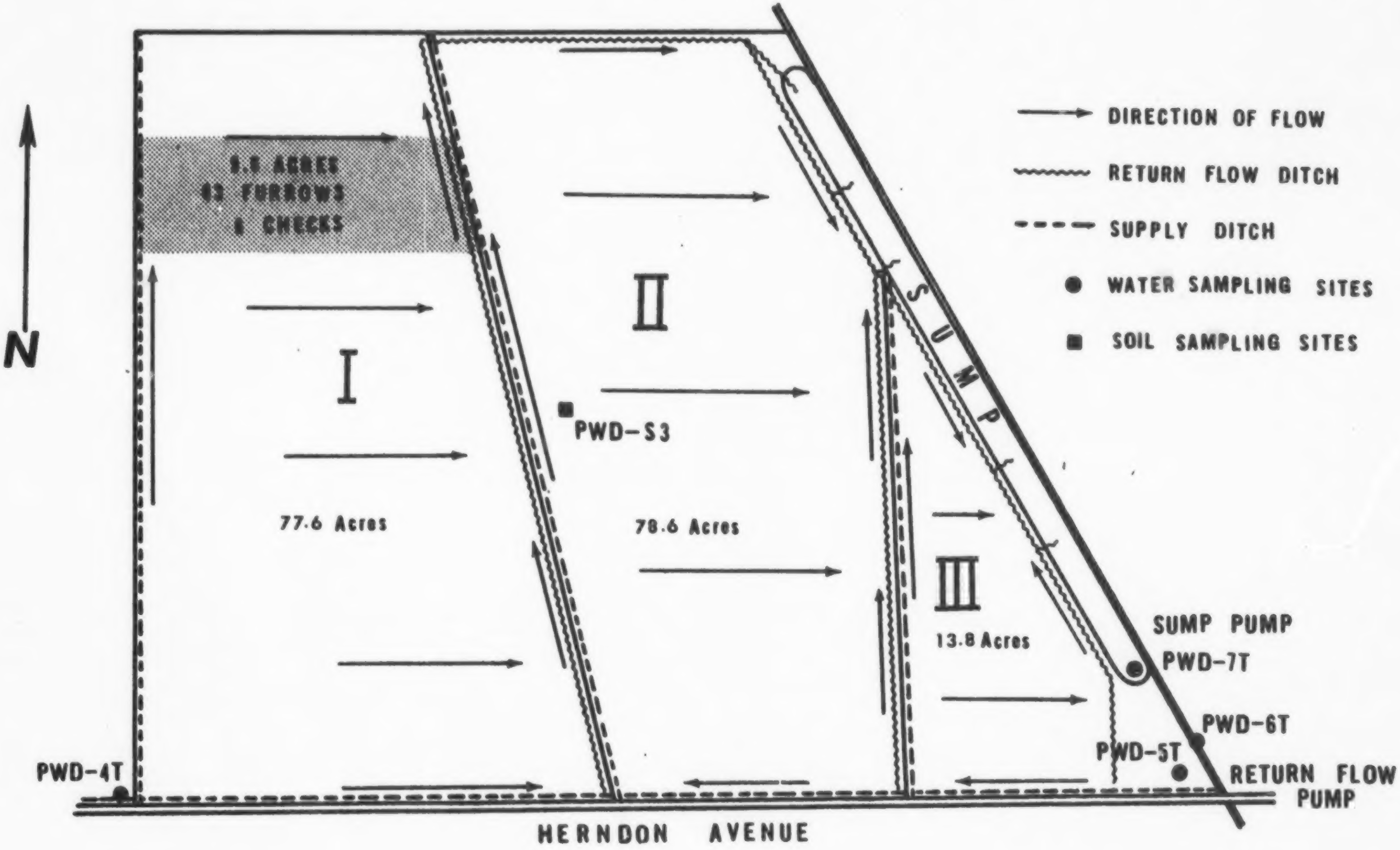

N
[illegible] ACRES
[illegible] FURROWS
[illegible] CHECKS
I
77.6 Acres
II
PWD-S3
78.6 Acres
III
13.8 Acres
SUMP
SUMP PUMP
PWD-7T
PWD-6T
PWD-5T
PWD-4T
RETURN FLOW
PUMP
HERNDON AVENUE
DIRECTION OF FLOW
RETURN FLOW DITCH
SUPPLY DITCH
WATER SAMPLING SITES
SOIL SAMPLING SITES

FIG. VII-11: FURROW IRRIGATED, 170 ACRE TOMATO FIELD, PANOCHE WATER DISTRICT

1975 IRRIGATION SEASON

Table VII-17:

Tailwater Production Test* in Furrow-Irrigated Tomato Field in Panoche Water District 1975

Irrigation Water Applied	2.20 ac-in/ac
Tailwater Production	0.63 ac-in/ac
% Tailwater Production	28.7% of water applied

* Test made on July 12-17, 1975 in Subfields I and II (156 acres). Tailwater was measured by the pump in return flow ditch (PWD-7T).

Table VII-18:

Tailwater Production Test in Portion* of 170 Acres Furrow-Irrigated Tomato Field in Panoche Water District July 16, 1975

Irrigation Water Applied*	3.75 ac-in/ac
Tailwater Production	0.90 ac-in/ac
% Tailwater Production	24% of water applied

	EC (μmhos/cm)	Turbidity (JTU)
Supply water at PWD-4T	391	112
Supply water at Check 32	436	112
Tailwater from Checks 27-32	510	2,244

* Subfield I, Checks 27-32, 9.6 acres, 63 furrows.

are usually in good agreement with that obtained from line operated laboratory conductivity bridges, but field turbidity measurements may be higher than those obtained with a laboratory turbidimeter. The EC of the supply water at PWD-4T was 391 µmhos/cm, the supply water at check 32 was 436 µmhos/cm, and the tailwater produced from checks 27-32 was 510 µmhos/cm. It is commonly believed that the salinity of surface runoff waters is not usually different from that of the applied irrigation water. In this particular case, we monitored increases in salinity. Further evidences will be given. With regards to turbidity, the supply water at PWD-4T, and at check 32, was 112 JTU, while the tailwater from checks 27-32 was 2,244 JTU. The tailwater was so turbid that a fourfold dilution with distilled water was required to obtain measurements.

Table VII-19 shows additional detailed data from individual furrows. In checks 27-32, 2-3 furrows each were monitored individually for the rate of water flow in gpm, and for the EC and turbidity of both the siphoned water and tailwater produced at the end of each furrow. The average application rate in these furrows was 37 gpm. The average EC of the inflow water was 376 µmhos/cm, while the EC for the outflow water was 546 µmhos/cm. It appears that a substantial pickup of salts occurred as the water in the furrows leached salts that had accumulated on the furrow beds by mid-irrigation season. The average turbidity in the applied water was 124 JTU as compared to 2,080 JTU in the runoff waters. There is no question that this Panoche soil series is highly erodible, and does not appear to have much aggregation. It tends to slake upon wetting. The tailwater produced from this tomato field was not discharged, but recovered and reused. With an increased time of travel and reduction of water flow velocities in the sump, the turbitity of tailwater was typically from 275 to 300 JTU at the return flow sump.

Table VII-19:

Tailwater Production Test in Portion* of 170 Acres
Furrow-Irrigated Tomato Field in Panoche Water District
July 16, 1975

Furrow No. Check No.	Inflow			Outflow	
	Q (gpm)	EC (μmhos/cm)	Turbidity (JTU)	EC (μmhos/cm)	Turbidity (JTU)
4/27	35	380	120	425	1650
9/27	35	↓	↓	425	1575
4/28	34	↓	↓	430	1100
9/28	42	↓	↓	430	1600
4/29	40	↓	↓	560	2800
9/29	40	↓	↓	560	2800
4/30	41	↓	↓	580	2800
9/30	34	↓	↓	580	2800
3/31	36	370	130	600	2000
5/31	35	↓	↓	600	2000
8/31	37	↓	↓	600	2000
3/32	34	↓	↓	620	2000
5/32	32	↓	↓	620	2000
8/32	31	↓	↓	620	2000
Furrow Average	37	376	124	546	2080

---

*Sub-field I, Checks 27-32, 9.6 acres, 63 furrows, 2 siphons (1½ inch size) per furrow.

Table VII-20 gives the soil data from the PWD-S3 sampling site in the tomato field. It was comparatively low in salinity, gypsum, and boron.

D. Los Banos Wildlife Area

Within the Mendota-Crows Landing Return Flow Group a mutually beneficial arrangement has evolved among the various water users. During the irrigation season part of the irrigation return flow generated by crop irrigators is utilized for the irrigation of pastures (grassland) which are grazed by cattle, and to provide suitable wildlife habitats, including wetlands. On the other hand, during the nonirrigation season, the distribution system used for conveying irrigation water is utilized for delivering freshwater to flood portions of the grasslands and wildlife refuges, for wintering waterfowl. Historically, there were about 5 million acres of permanent to semipermanent marshlands in the Central Valley, but now it has been reduced to about 1 million acres. Since 25% of all migratory waterfowl, primarily ducks and geese, in the North American continent use the Pacific Flyway (for nesting or migrating through the Central Valley) attempts are being made to restore suitable habitat and refuges by government and private organizations for both migrating and resident (2-3% of total) birds.

One of only six wildlife refuge units operated by the California Department of Fish and Game was selected as a study area. The 3,200-acre Los Banos Wildlife Area, as shown in Figure VII-12, practices a multiobjective refuge management that not only provides for waterfowl hunting in winter, but also for other types of hunting, fishing, camping and picnicking, along with various kinds of nature study. Table VII-21 documents the recreational usage of the Los Banos Wildlife Area in fiscal year 1974-75.

The single most important operational activity in this refuge, in terms of management, is the manipulation of water. Proper water management is

Table VII-20:

Soil Data from One Sampling Site in the Tomato Field in Panoche Water District

1975

Depth (ft.)	EC_e* (mmhos/cm)	Estimated soluble salts (tons/ac-ft soil)	Gypsum (tons/ac-ft soil)	Boron (mg/ℓ)
0-½	0.71	0.41	0.07	0.64
½-1	0.56	0.31	0.07	0.60
1-1½	0.61	0.31	0.17	0.40
1½-2	0.57	0.28	0.15	0.40
2-3	0.55	0.26	0.33	0.50
3-4	0.58	0.27	0.29	0.64
4-5	0.53	0.25	0.33	0.70
5-6	0.57	0.28	1.00	0.75
6-7	0.53	0.23	0.14	0.64
7-8	0.55	0.19	0.22	0.80
8-9	0.67	0.26	0.21	0.90
9-10	0.88	0.38	0.24	1.30
10-11	0.82	0.32	0.22	1.25
11-12	0.83	0.34	0.14	1.10

* EC_e is EC of soil saturation extract.

FIG. VII–12

LOS BANOS WILDLIFE AREA

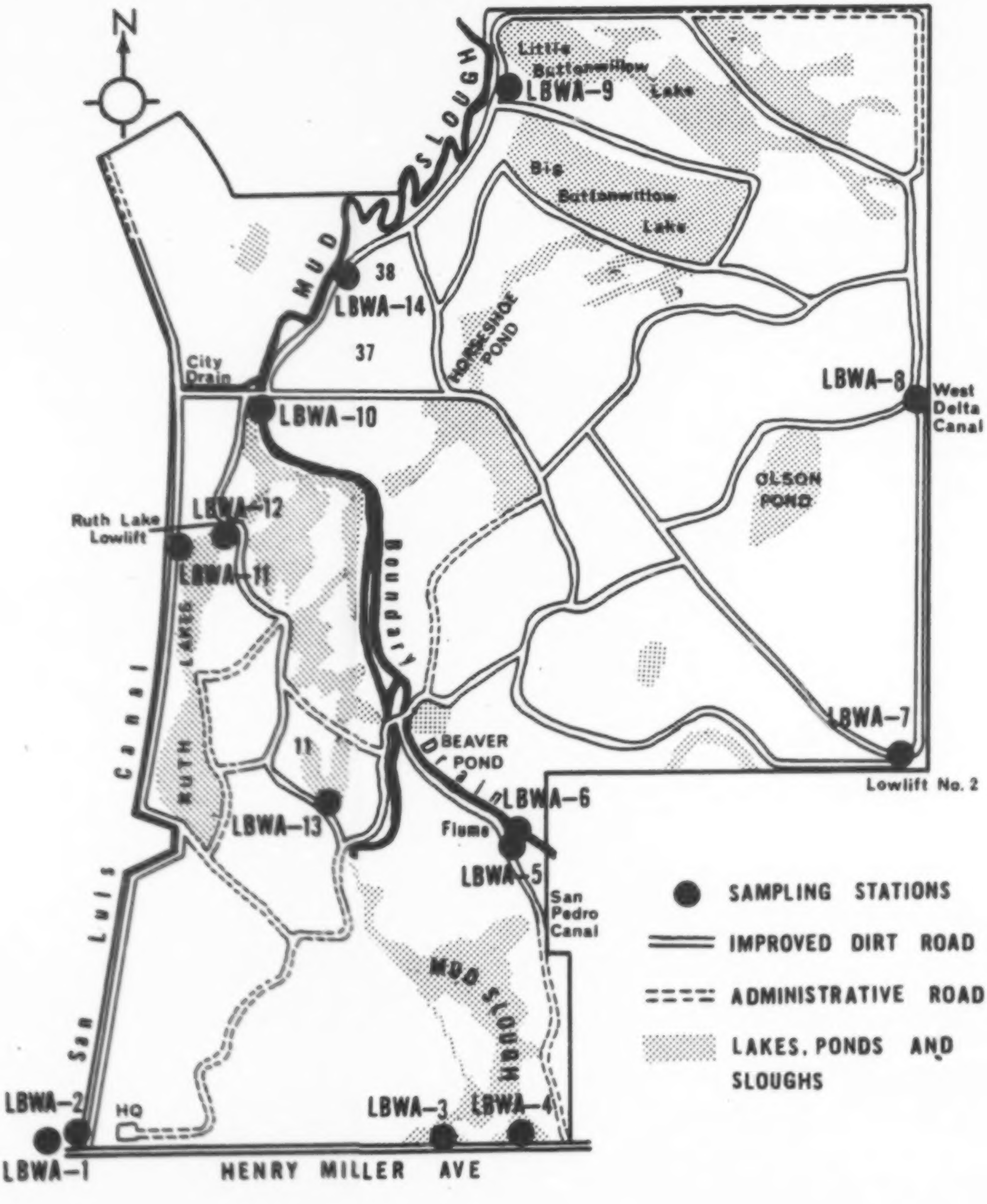

N
Little Buttonwillow Lake
LBWA-9
MUD SLOUGH
Big Buttonwillow Lake
38
LBWA-14
37
HORSESHOE POND
City Drain
LBWA-10
LBWA-8
West Delta Canal
OLSON POND
Ruth Lake Lowlift
LBWA-12
LBWA-11
RUTH LAKES
Boundary Drain
San Luis Canal
11
BEAVER POND
LBWA-7
Lowlift No. 2
LBWA-13
LBWA-6
Flume
LBWA-5
San Pedro Canal
MUD SLOUGH
LBWA-2
HQ
LBWA-3
LBWA-4
LBWA-1
HENRY MILLER AVE
SAMPLING STATIONS
IMPROVED DIRT ROAD
ADMINISTRATIVE ROAD
LAKES, PONDS AND SLOUGHS

Table VII-21: Recreational Usage of the Los Banos Wildlife Area during July, 1974 through June, 1975

Hunting:	Season	Number of Hunters	Harvest or Number Bagged
Ducks, Geese, Coots	Oct. 19 - Jan. 19	4,904	9,952
Pheasant	Nov. 16 - Dec. 8	1,227	175
Rabbit	Jan. 20 - Oct. 18	315	388
Total		6,446	

Nonhunting:	Number of People
Fishing	8,419
Frogging	373
Sightseeing	1,161
Nature Study	920*
Camping	177†
Activity Unknown	2,714
Total	13,764

* Includes organized groups from schools, ranging from elementary to university levels, birdwatching by various local Audobon Society, etc.

† 571 registered visitors actually camped. Visitor registration form was not designed to indicate more than one activity and so the remainder presumably were recorded under other activities.

necessary to establish and maintain both wetland and upland habitats for the above recreational uses. The Los Banos Wildlife Area has 80,000 lineal feet of supply and drain ditches, and 400 acres of permanent (impounded) water. About 2,400 acres of marshland are annually ponded for waterfowl and other marsh-associated wildlife, starting in June with optimum water levels attained by mid-October. These ponds are kept flooded until late April. In addition, irrigation is required for vegetation in upland areas that provide food and cover for mammals and birds.

Fourteen sampling stations were monitored in and around the Los Banos Wildlife Area, which are described in Appendix Table 25 and shown on the map in Figure VII-12. Monthly water flow, where available, and water quality data are reported in Appendix Table 26. Station LBWA-1 is the San Luis Federal Drain for the U.S. Bureau of Reclamation's San Luis Project, south of our study area. This drain conveys tile effluents only, and terminates at the Kesterson Reservoir, east of Gustine. The water in the San Luis Federal Drain is not reused, and our sampling of the drain was only carried out to compare the irrigation return flow containing tile effluents with that containing a mixture of collected surface irrigation return flow, part of which may have been reused more than once in the Mendota-Crows Landing Return Flow Group. Not to be confused with the San Luis Federal Drain is the San Luis Canal (LBWA-2 and LBWA-11), from which the wildlife area obtains part of its supply water. Attempts were made to get flow estimates for each of the 13 stations in the Los Banos Wildlife Area, but were successful at only five stations.

Tables VII-22 and VII-23 present a summary of the water quality data for LBWA-1, the major inflows and outflows, and internal stations in the Ruth Lake complex. Based on currently available estimates on inflows to the

Table VII-22: Summary of Water Quality Data in the Los Banos Wildlife Area from May through October, 1975.

Station	Description	Q (ac-ft)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)
LBWA-1*	San Luis Federal Drain		5,986	4,493	7	16	9.47
Inflow to Wildlife Area:							
LBWA-2†	San Luis Canal	2,412	2,259	1,489	75	171	3.56
LBWA-3	Municipal Sewage Effluent		2,447	1,573	6	11	2.37
LBWA-4	Mud Slough inlet		1,843	1,136	73	149	2.14
LBWA-5‡	Boundary Drain	15,866	1,112	621	49	124	0.28
LBWA-6	San Pedro Canal	3,508	641	445	77	177	0.17
LBWA-8	West Delta Canal	1,623	881	503	39	86	0.24
Outflow from Wildlife Area:							
LBWA-10	Mud Slough outlet		1,160	688	50	134	2.37
LBWA-14	Field 37 and 38 discharge		1,815	1,097	16	34	1.41
LBWA-9	Buttonwillow Lake outflow		1,394	721	32	78	0.20
Internal Stations**:							
LBWA-12	Ruth Lake Low lift pump		1,875	1,115	30	59	1.17
LBWA-13	Ruth Lake discharge		2,583	1,649	28	57	2.48

* not used in wildlife area

† LBWA-11 same as LBWA-2

‡ LBWA-7 same as LBWA-5

** also LBWA-11 and LBWA-2

Table VII-23: Summary of Nitrogen and Oxygen-Demand Quality Parameters in the Los Banos Wildlife Area from May through October of 1975.

Station	Description	Total N	Organic-N	NH_4-N	NO_3-N	NO_2-N	BOD	DO
		←		mg per liter				→
LBWA-1	San Luis Federal Drain	1.02	0.93	0.32	0.02	0.001	1.8	8.9
Inflow to Wildlife Area:								
LBWA-2	San Luis Canal	4.94	1.02	0.65	3.01	0.066	2.1	8.2
LBWA-3	Municipal Sewage Effluent	7.33	4.25	3.25	0.14	0.094	4.6	3.7
LBWA-4	Mud Slough inlet	2.28	1.47	0.62	0.04	0.001	4.5	7.8
LBWA-5	Boundary Drain	2.38	1.60	0.09	0.70	0.056	2.2	9.3
LBWA-6	San Pedro Canal	1.48	1.02	0.09	0.36	0.011	3.0	9.8
LBWA-8	West Delta Canal	2.26	1.12	0.27	0.76	0.055	2.1	10.1
Outflow from Wildlife Area:								
LBWA-10	Mud Slough outlet	2.28	1.30	0.05	0.05	0.059	3.3	9.3
LBWA-14	Field 37 and 38 discharge	2.62	2.44	0.13	0.06	0.002	5.0	11.2
LBWA-9	Buttonwillow Lake discharge	2.70	2.59	0.11	0.01	0.002	3.0	--
Internal Stations:								
LBWA-12	Ruth Lake low lift pump	2.36	2.29	0.06	0.05	0.005	4.8	9.2
LBWA-13	Ruth Lake discharge	2.62	2.44	0.13	0.06	0.001	10.6	10.8

refuge, LBWA-5 is the major supply water for the monitored period. Mud Slough is known to convey substantial flows, but what portion of it is utilized is unknown, since an estimate on water lifted for Ruth Lake (LBWA-12) was not possible to obtain and attempts to measure flow into (LBWA-4) and flow out (LBWA-10) also were not successful. The costs of installing additional water flow measuring devices and structures, other than staff gages and current velocity measurements, were too prohibitive for this project.

An examination of the quality of inflow water shows two types of water; namely, moderately saline-high boron waters at LBWA-2, LBWA-3 and LBWA-4, and relatively nonsaline-low boron waters at LBWA-6 and LBWA-8. The latter waters primarily represent the quality of freshwater found in the Delta-Mendota Canal, while the former is typical of irrigation return flow and reused return flow. Boundary Drain (LBWA-5) had a salinity level slightly higher than LBWA-6 and LBWA-8, but with a similar boron concentration. The San Luis Federal Drain (LBWA-1), in comparison, is extremely saline, high in boron, and low in suspended matter. This is expected, since the drain conveys tile effluents only. The quality of the tile drainage is such that it has limited beneficial uses.

Three outflow stations were sampled in this study area. LBWA-10 is a downstream station in Mud Slough above the outfall of the Los Banos City Drain. Comparing the inlet (LBWA-4) and outlet (LBWA-10) of Mud Slough, it is noted that salinity is lower at the outlet than in the inlet, while suspended matter and boron are nearly the same. Complicating this comparison are other sources of excess supply water which may eventually discharge into Mud Slough, namely, San Luis Canal (LBWA-2, LBWA-11) and Boundary Drain (LBWA-5). The former is saline while the latter is less saline. Outflow Station LBWA-14 is for the discharge of water into Mud Slough from Fields

37 and 38, and others, that receive much of their supply water from Boundary Drain (LBWA-5) and Mud Slough (LBWA-4). A substantial reduction in suspended load is noted when compared to LBWA-5 and LBWA-4, due to the deposition of silt and clay. LBWA-9 is a discharge station for Buttonwillow Lake, which receives much of its supply water from the West Delta Canal (LBWA-8). In our monthly sampling this station was flowing only in June, so only one water sample was obtained. The quality of LBWA-9 is similar to that of LBWA-8, except for a slight increase in salinity, which was expected due to evaporation losses from the lake surface.

The Upper and Lower Ruth Lakes receive their supply water from Mud Slough at LBWA-12 and San Luis Canal at LBWA-11, and between LBWA-11 and LBWA-2. Mud Slough and San Luis Canal contain moderately saline, turbid, high-boron waters. LBWA-12, Ruth Lake low lift pump, had nearly the same salinity level as Mud Slough, but lower suspended matter and boron levels and the discharge water, LBWA-13, had a similar salinity level as the San Luis Canal, but was lower in suspended matter and boron. With regards to these quality parameters, the major change appears to be a reduction in the sediment load by impoundment of water in the Ruth Lake complex.

Table VII-23 presents a summary of the different nitrogen species, dissolved oxygen (DO), and biochemical oxygen demand (BOD) in the waters of the Los Banos Wildlife Area. As pointed out from data presented in Table VII-22, San Pedro Canal, Boundary Drain, and West Delta Canal were low in boron and comparatively lower in salinity as compared to San Luis Canal, Mud Slough, and the sewage effluent. For these inflow waters, the sewage effluent (LBWA-3) contained the highest Total N, organic-N, NH_4-N and BOD, and also the lowest DO. San Luis Canal had moderate amounts of N, primarily in the NO_3-N form, yet all other parameters were similar to other inflows (except LBWA-3). The range of Total N between 1.5 to 2.4, primarily in the organic-N and NO_3-N forms, is typical of irrigation return flows. With the exception of Mud Slough, the BOD were also typical of irrigation return flows. BOD in Mud Slough was probably higher due to animal and plant residues.

With regards to outflow, the most noticeable change in the distribution of various N species was the slight increase in organic-N and the concurrent reduction in NO_3-N. A similar finding is noticed in the internal stations for the Ruth Lake Complex. BOD in LBWA-13 was significantly higher, due primarily to the decay of marshland type vegetation in stagnant to slow-moving water; however, DO was high. It appears that a substantial reduction in Total N, in particular NO_3-N, occurred in Ruth Lake when compared to San Luis Canal, the canal being a major source of water for this lake complex. This reduction is attributed to N uptake by algae and by marshland vegetation. In addition, NO_3-N was probably reduced through denitrification losses.

In summary, the Los Banos Wildlife Area contributes to the abatement of pollution by reusing irrigation return flows from croplands and pasturelands, and reducing the sediment and NO_3-N loads in these return flows. Although organic-N tends to increase, it is not a major pollutional hazard as NO_3-N or NH_4-N because organic-N may not become completely mineralized at downstream location, or in receiving waters. Similar conclusions may be reached for other water reuse areas such as the grasslands.

VIII. SACRAMENTO VALLEY FIELD STUDIES

A. Sacramento Valley Return Flow Group.

A return flow group has applied for and received an NPDES permit in the Sacramento Valley. The permittee is known as the Sacramento Valley Water Quality Committee, and is chaired by Mr. D. E. Kienlen, Engineer, and Col. A. E. McCollum, Manager-Secretary. This return flow group has more than 47 cosigners who belong to either the Sacramento Valley Water Quality Committee or the California Central Valley's Flood Control Association. These cosigners include 14 irrigation and water districts, 20 reclamation districts, 5 drainage districts, and 8 individual landowners. In addition to Mr. Kienlen and Col. McCollum, the current officers for the joint Water Quality Committee and Flood Control Association are Mr. G. R. Harris,Chairman, Mr. B. Stengly, Vice Chairman, and Mr. R. D. Clark, Secretary-Treasurer.

The Sacramento Valley Return Flow Group's boundaries extend over an area of one million acres of irrigated lands (Figure VIII-1) from as far north as Hamilton City to as far south as Sacramento. The Group discharges irrigation return flows and other return flows into the Sacramento and Feather Rivers through 13 major drains. The NPDES permit requires monthly monitoring of Q, EC, and SS from 16 NPDES discharge points, as well as quarterly monitoring of 2 supply points located on the Sacramento River at Hamilton City and on the Feather River at Thermolito. Unlike the Mendota-Crows Landing Return Flow Group which has a self-monitoring program and determines their own water quality data, the Sacramento Return Flow Group has contracted out the monitoring and quality analyses to the California Department of Water Resources.

Because of the extensive nature and large number of discharge points within the Sacramento Group, the Glenn-Colusa Irrigation District (GCID) and

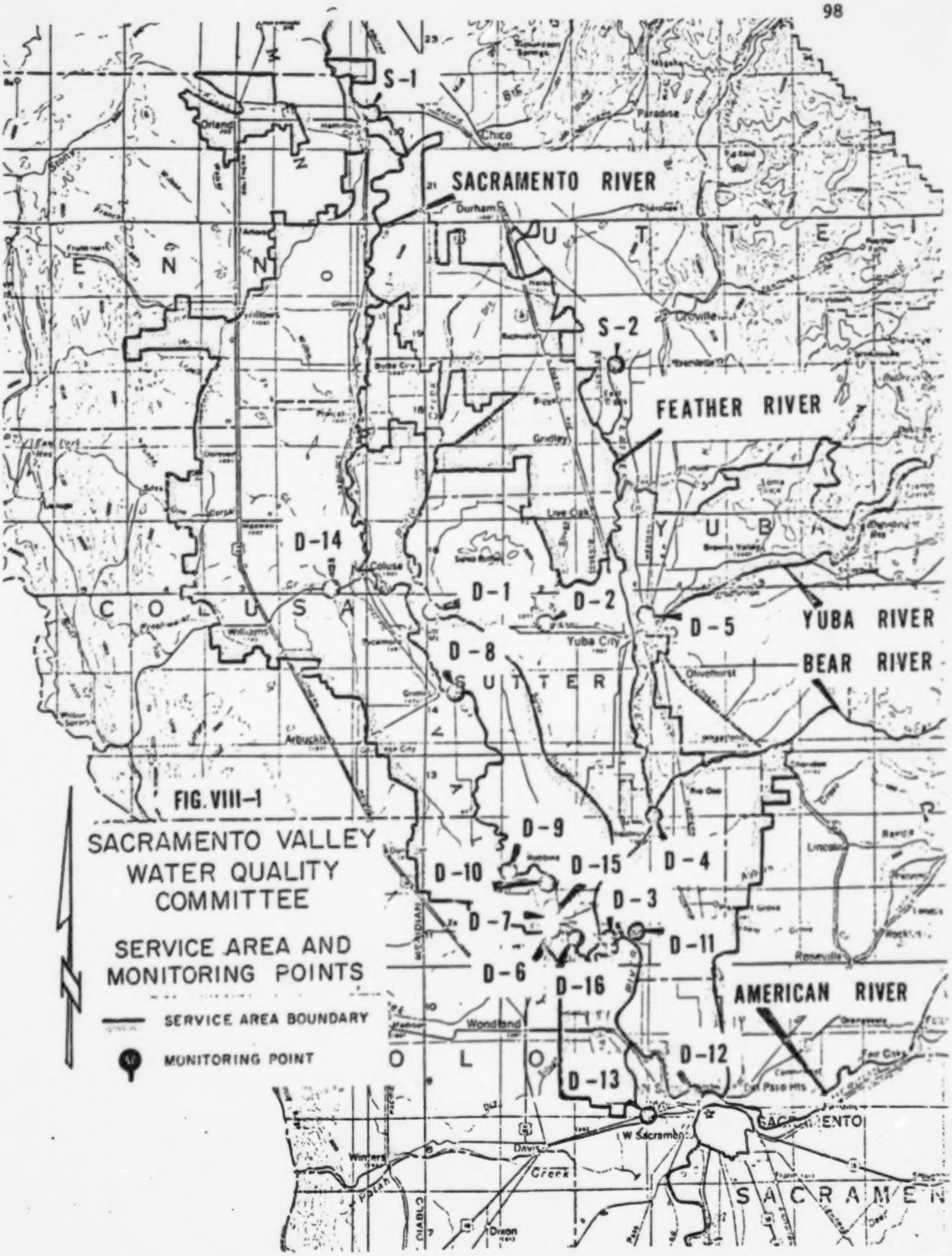

S-1
SACRAMENTO RIVER
Chico
Paradise
Durham
Orland
Willows
Oroville
S-2
FEATHER RIVER
Gridley
Live Oak
Y U B A
G L E N N
B U T T E
D-14
Colusa
D-1
D-2
C O L U S A
D-5
YUBA RIVER
Yuba City
D-8
S U T T E R
Williams
BEAR RIVER
Olivehurst
Arbuckle
D-9
D-15
D-4
D-10
D-3
D-7
D-11
D-6
D-16
AMERICAN RIVER
Lincoln
Roseville
Woodland
D-12
D-13
Y O L O
W Sacramento
SACRAMENTO
Davis
Winters
Dixon
Putah Creek
S A C R A M E N
SERVICE AREA BOUNDARY
MONITORING POINT

FIG. VIII-1

SACRAMENTO VALLEY
WATER QUALITY
COMMITTEE

SERVICE AREA AND
MONITORING POINTS

the Colusa Basin Drain (CBD) were selected for field studies in this project. GCID (Fig. VIII-2) is a typical district in the valley, with flooded rice culture as the major crop. Within this district, four rice fields were monitored in 1975. GCID receives its supply water primarily by diverting water from the Sacramento River, near Hamilton City (S-1), and discharges its return flow into CBD (Fig. VIII-3). The NPDES permit includes three stations on the Colusa Basin Drain (Fig. VIII-1); D-14, at the crossing with Highway 20; D-6, at the Colusa Basin Drain outfall into the Sacramento River above Knights Landing; and D-7, Reclamation District 787's drain near the confluence with CBD. This EPA project is also monitoring water quality at station D-14 (CBD-3 in Fig. VIII-3), and at a station upstream from D-6 and D-7 (CBD-1 in Fig. VIII-3).

B. Glenn-Colusa Irrigation District.

The 163,700 acre Glenn-Colusa Irrigation District (GCID) is located on the west side of the Sacramento Valley (Fig. VIII-2). In the 1975 irrigation season, 835,400 ac-ft of water (Table VIII-1) was delivered to 132,436 acres of crop and refuge lands (Appendix Table 27), 71% of which were devoted to rice production. Supply waters diverted from the Sacramento River and from Stony Creek, D-14 in Figure VIII-4, are conveyed by a main canal that runs along the district's western boundary, more or less parallel to Highway Interstate 5.

GCID practices reuse of its irrigation return flows with either gravity diversions or drain pumps. Table VIII-1 indicates 221,900 ac-ft, or 27% of the diverted water, was captured and reused in 1975. Lateral spills were about 4% of the total diversions, or 34,300 ac-ft. The surface return flows from GCID were estimated to be 243,500 ac-ft, or 29% of the total diversions.

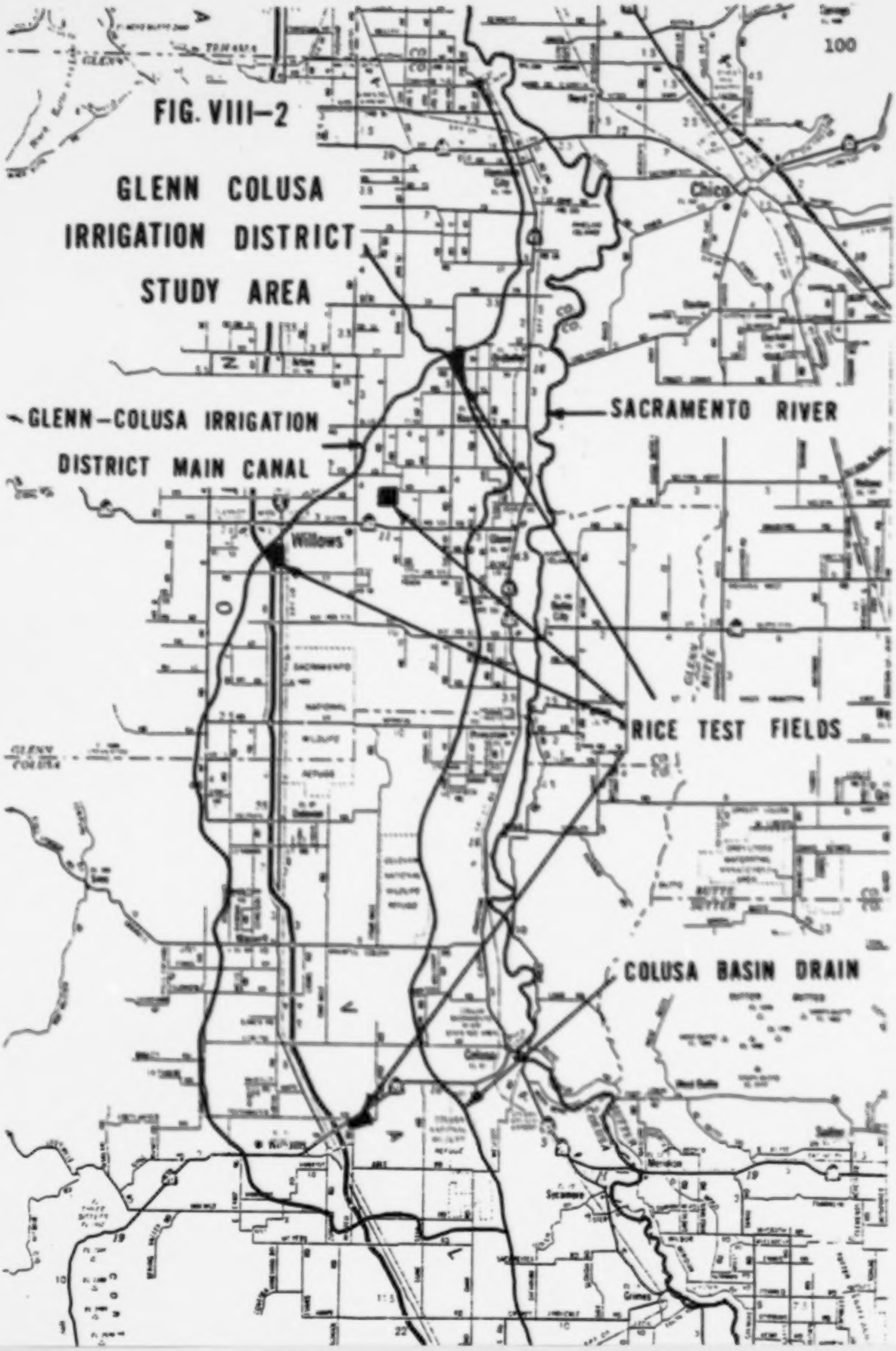


FIG. VIII-2

GLENN COLUSA IRRIGATION DISTRICT STUDY AREA

GLENN-COLUSA IRRIGATION DISTRICT MAIN CANAL
SACRAMENTO RIVER
RICE TEST FIELDS
COLUSA BASIN DRAIN
Chico
Willows

FIG. VIII-3

COLUSA BASIN DRAIN

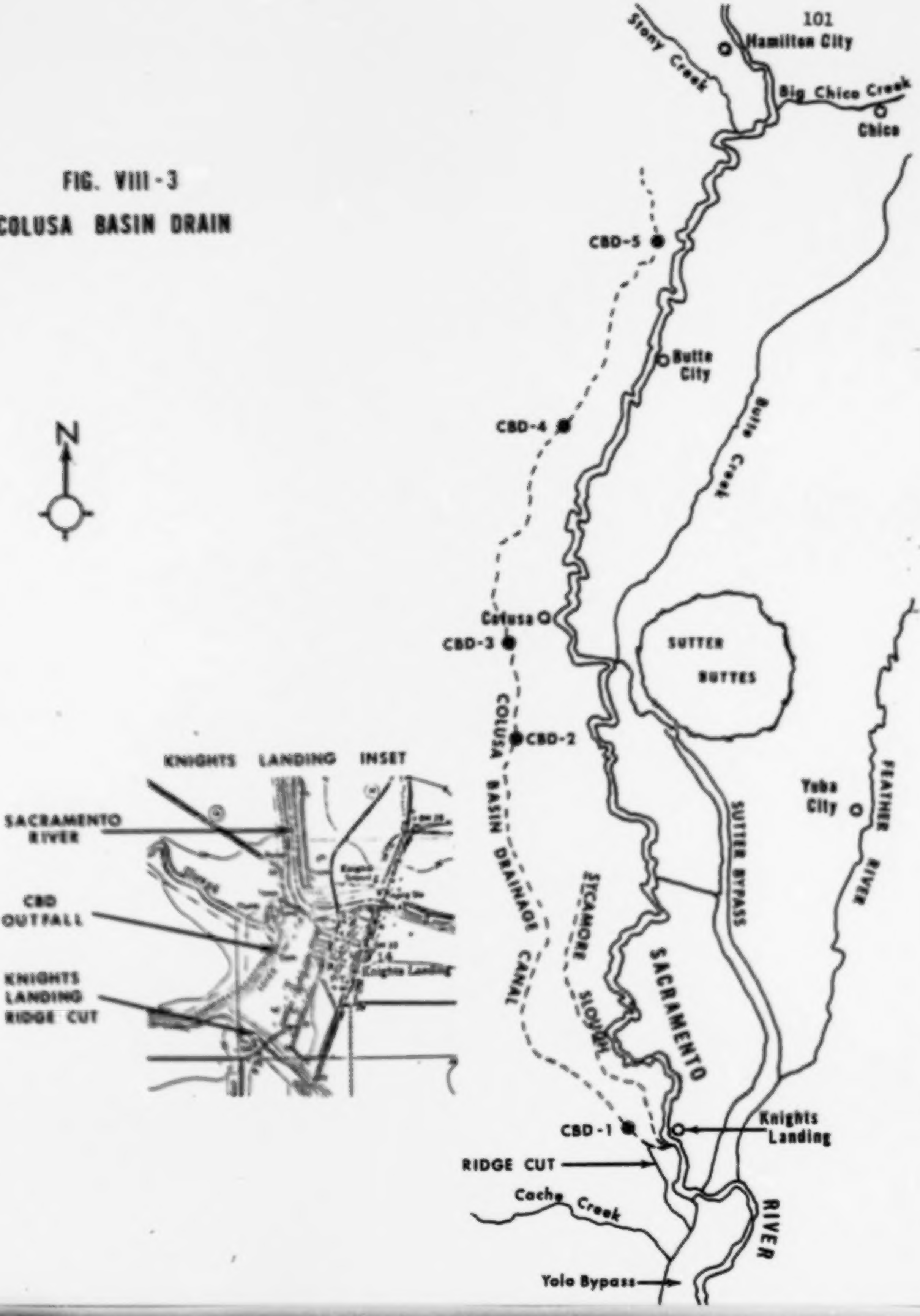
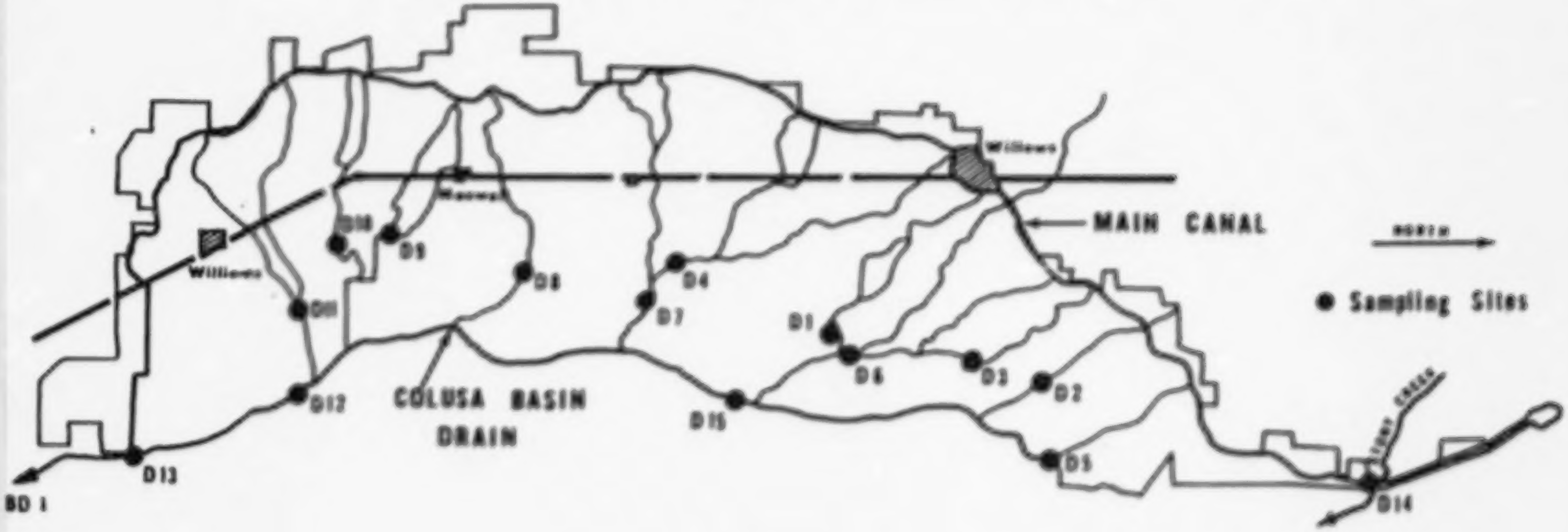

101
Stony Creek
Hamilton City
Big Chico Creek
Chico
CBD-5
Butte City
Butte Creek
CBD-4
N
Colusa
CBD-3
SUTTER
BUTTES
CBD-2
COLUSA BASIN DRAINAGE CANAL
SYCAMORE SLOUGH
SACRAMENTO
SUTTER BYPASS
Yuba City
FEATHER RIVER
CBD-1
Knights Landing
RIDGE CUT
Cache Creek
RIVER
Yolo Bypass
KNIGHTS LANDING INSET
SACRAMENTO RIVER
CBD OUTFALL
KNIGHTS LANDING RIDGE CUT
Knights Landing

Table VIII-1: Summary of Monthly Water Flows in Acre-Feet in the Glenn-Colusa Irrigation District During the 1975 Irrigation Season.

Description	April	May	June	July	August	September	October	Total
Supply Water:								
Sacramento River Diversion	65,900	141,100	146,800	142,400	137,900	59,600	17,600	711,300
Stony Creek Diversion	25,800	29,100	19,300	23,700	18,200	2,900	5,100	124,100
Total Diversion	91,700	170,200	166,100	166,100	156,100	62,500	22,700	835,400
Drain Recapture:								
Drain Pumps	6,700	30,900	33,400	35,600	32,000	9,400	200	148,200
Gravity Diversions	5,000	17,900	14,500	15,400	15,800	4,300	800	73,700
Total Recapture	11,700	48,800	47,900	51,000	47,800	13,700	1,000	221,900
Lateral Spills:	2,700	9,400	3,400	5,500	5,600	6,700	1,000	34,300
Drain Outflow:	12,500	39,700	30,000	41,600	52,100	51,800	15,800	243,500

FIGURE VIII-4

GLENN-COLUSA IRRIGATION DISTRICT


Willows
MAIN CANAL
NORTH
● Sampling Sites
Maxwell
Williams
D1
D2
D3
D4
D5
D6
D7
D8
D9
D10
D11
D12
D13
D14
D15
COLUSA BASIN DRAIN
Stony Creek
BD 1

GCID's irrigation return flows are conveyed by 11 lateral drains (Fig. VIII-4) to the upper reaches of the Colusa Basin Drainage Canal. Monthly drain outflows for the 11 lateral drains are tabulated in Appendix Table 28.

Table VIII-2 presents the seasonal flow-weighted average quality of GCID's supply water, its 11 lateral drains, and a calculated overall district drain outflow. The quality and flow data are reported in Appendix Table 29. GCID's supply water is of extremely high quality, while its surface return flow is nearly the same seasonal quality as that of the supply water for the Mendota-Crows Landing Return Flow Group (see Table VII-1).

Tables VIII-3 and VIII-4 give the relation between TDS and EC, and SS and turbidity. Except for D-2 and D-3, TDS is highly correlated to EC. The r-values for the turbidity vs. SS relationship in these stations were, in general, not as high as the salinity parameters; however, good correlations were obtained for many of them. As in the Mendota-Crows Landing Return Flow Group, the slopes and y-intercepts vary considerably.

Table VIII-5 analyses water, salt, and sediment flows in GCID. When compared to Panoche Drainage District (Table VII-9), GCID has a slightly lower surface drainage index (0.29 vs. 0.31), but a higher unit applied water (6.31 vs. 3.23 ft) and a higher unit surface drainage (1.84 vs. 0.91 ft). These differences may be attributed to the predominance of flooded rice culture in GCID, as compared to field and row crops in Panoche Drainage District, and to the greater reuse of drain waters in GCID (29%) compared to Panoche Water District (1.3%).

It is of interest to note that the salt balance index, defined as the ratio of the salt load in the surface return flow to that of the supply water, is less than unity, i.e., 0.61. Indices less than unity are indicative of salt accumulation in the soil as soluble and insoluble salts and/or salts

Table VIII-2: Flow-Weighted Average Water Quality

in the 1975 Irrigation Season for Glenn-Colusa Irrigation District

Description	Seasonal Flow (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)
Supply Water:					
D-14	835,400	180	116	15	24
Lateral Drains*:					
D-5	25,000	315	187	16	31
D-2	5,300	335	201	19	37
D-3	50,200	307	177	8	16
D-6	21,800	320	189	19	33
D-1	4,000	417	239	11	17
D-4	9,800	598	374	26	33
D-7	17,300	361	212	40	42
D-8	17,400	456	307	39	69
D-9	13,400	349	206	17	23
D-10	12,900	445	251	22	35
D-11	17,700	675	514	42	79
District Drain Outflow*:	194,800	391	244	22	36

* based on measured monthly flows (Appendix Table 28)

Table VIII-3: Relation between TDS and EC in the Glenn-Colusa Irrigation District Monitoring Stations for the 1975 Irrigation Season

Station	Range of Values		Coefficients for TDS = $a_o + a_1$ EC		Correlation Coefficient
	EC (µmhos/cm)	TDS (mg/ℓ)	a_0	a_1	r
Supply Canal:					
D-14	115-325	80-177	51.653	0.386	0.89
Lateral Drains:					
D-5	293-421	174-265	-41.371	0.724	0.98
D-2	298-385	140-235	141.520	0.178	0.19
D-3	270-524	158-226	121.025	0.186	0.69
D-6	300-458	166-261	7.864	0.566	0.98
D-1	371-677	171-404	-32.489	0.662	0.89
D-4	526-1,103	329-603	85.230	0.472	0.99
D-7	324-599	201-369	-24.775	0.653	0.99
D-8	392-984	234-615	-34.205	0.657	0.99
D-9	328-522	191-336	-54.460	0.743	0.99
D-10	333-984	190-615	-25.285	0.640	0.99
D-11	538-966	314-603	-33.857	0.630	0.99

Table VIII-4: Relation Between Turbidity and SS in the Monitoring Stations in Glenn-Colusa Irrigation District for the 1975 Irrigation Season

Station	Range of Values		Coefficients for $SS = a_0 + a_1$ Turbidity		Correlation Coefficient
	Turbidity (JTU)	SS (mg/ℓ)	a_0	a_1	r
Supply Canal:					
D-14	7-53	7-53	8.144	0.883	0.84
Lateral Drains:					
D-5	9-82	14-94	-3.964	1.927	0.88
D-2	5-77	1-117	2.134	1.500	0.96
D-3	3-13	2-34	0.912	6.691	0.28
D-6	12-38	18-79	2.388	1.597	0.73
D-1	3-23	9-53	0.895	1.723	0.73
D-4	14-64	17-99	4.809	1.518	0.95
D-7	9-74	7-121	0.207	1.667	0.94
D-8	21-85	34-190	-10.87	2.029	0.95
D-9	9-79	7-106	4.208	1.282	0.96
D-10	13-62	17-106	-3.720	1.770	0.99
D-11	21-69	39-111	5.136	1.712	0.97

Table VIII-5: Analysis of Water, Salt and Suspended Matter
for Glenn-Colusa Irrigation District in the 1975 Irrigation Season

Unit Applied Water = supply/irrig. acres = 835,400/132,436 = 6.31 ac-ft/ac

Unit Surface Drainage = surface discharge/irrig. acres = 243,500/132,436 = 1.84 ac-ft/ac

Surface Drainage Index = surface discharge/supply = 0.29

Salt (TDS) Input = 131,793 tons or 1,990 lbs/ac

Salt Output = 80,803 tons or 987 lbs/ac

Salt Balance Index = output/input = 0.61

Sediment (SS) Input = 27,267 tons or 412 lbs/ac

Sediment Output = 11,922 tons or 146 lbs/ac

Sediment Balance Index = output/input = 0.44

leached in percolating waters not collected by the drains. A similar analysis made on sediments gives an index of only 0.44. Apparently, much of the suspended matter in the supply water settles out in the rice fields and/or in the distribution-drainage systems. Although SS in Glenn-Colusa Irrigation District's supply water is low (24 mg/ℓ) as compared to that of Broadview Water District's (129 mg/ℓ), the inputs of sediment are comparable, 412 and 344 lbs/ac respectively, due to a higher unit applied water in the former.

Appendix Table 30 reports detailed quality data for the July and September water samples. As pointed out earlier, the salinity in the supply and drain waters was low. Total N ranged from 0.5 to 1.6 mg/liter, predominated by Organic-N rather than the mineralized forms of NH_4-N, NO_3-N, and NO_2-N. BOD ranged from 2.4 to 6.6 mg/liter, the higher values probably reflecting both sewage effluents discharged into drains by several municipalities, and animal wastes from pastures and wildlife refuges.

Rice Test Fields.

Figure VIII-2 shows the general locations of 4 monitored rice fields, ranging from 61 to 153 acres in size. Appendix Table 31 contains detailed information and data for these rice test fields with regards to the varieties of rice planted, dates of planting and harvest, and other cultural practices such as irrigation, fertilization, and weed control.

Table VIII-6 gives the analyses describing water balances for the four rice fields. Inflow was measured with a Hersey-Sparling propeller type totalizing meter while outflow was measured with either a 90° v-notch weir and a Leopold-Stevens water stage recorder, or a 6-inch Parshall flume and a water stage recorder. Evapotranspiration (ET) was estimated from Class A pan data (using a coefficient of 0.9), and seepage losses by difference. Table VIII-6 gives applied water ranging from 6.3 to 12.2 ac-ft/ac, and surface

Table VIII-6: Water Balance Data for Rice Test Fields

Glenn-Colusa Irrigation District, 1975 Season

Characteristic	Field Number			
	4	8	14	15*
Inflow, acre-feet/acre	7.97	6.83	6.27	12.23
Precipitation, acre-feet/acre	0.27	0.27	0.27	0.27
Total inflow, acre-feet/acre	8.24	7.10	6.54	12.50
Evapotranspiration ET, acre-feet/acre	3.37	3.37	3.37	3.37
Outflow, acre-feet/acre	0.87	1.19	1.86	2.42
Seepage, acre-feet/acre†	4.00	2.54	1.31	6.71
(Outflow/inflow) x 100	10.9%	17.4%	29.7%	19.8%
(Seepage/inflow) x 100	50.2%	37.2%	20.9%	54.9%
(Evapotranspiration/inflow) x 100	42.3%	49.3%	53.7%	27.6%

* Flow estimated due to equipment malfunction.

† Presumes moisture content of soil the same at harvest as just before initial flooding.

outflow ranging from 0.9 to 2.4 ac-ft/ac. The percentage of spill ranged from 11 to 30%, seepage from 21 to 55%, and ET from 28 to 54% of the applied water.

Table VIII-7 reports a summary of seasonal flow-weighted average quality parameters for inflow and outflow waters, based on detailed data presented in Appendix Tables 32-35. In general, the salinity in the applied water increases slightly, due to ET concentration of applied water and salt pickup from the submerged soils. As for suspended matter, except for Field 4, both turbidity and SS were lower in the surface outflow as compared to the inflow. This set of data supports the contention that rice fields act as settling basins for suspended matter. However, lateral drains (Table VIII-2) in GCID appear to have a higher suspended load. This may be attributed to the pickup of sediments in the drains, which were deposited during winter runoffs.

Table VIII-7 also contains seasonal flow-weighted N concentrations. The outflow water, in general, had greater Total N than the inflow. The dominant N species in both supply and drain waters is Organic-N. The mineralized forms of N (NH_4, NO_3, and NO_2) were lower in concentration. These rice fields received from 100 to 210 lbs N/ac fertilization (Appendix Table 31).

An extensive special study on nitrogen was made on the four rice test fields. Nitrogen (Total N, Organic-N, NH_4-N, NO_2-N, and NO_3-N) concentrations were determined in water samples obtained at the inflow and outflow points, in the floodwater, and in the soil solution (seepage water) with suction probes. Soil samples were also analyzed for various forms of N to the 3-ft depth. Field 15, the only rice field to receive a top-dressing of N fertilizer (second application) was intensively monitored during and after the aerial broadcast of $(NH_4)_2SO_4$. A complete N balance was developed for Field 8. The details of this special investigation are reported in Ms. Linda Wagenet's M.S. Thesis in Water

Table VIII-7: Seasonal Flow-Weighted Average Water Quality in Monitored Rice Fields for the 1975 Irrigation Season

	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	Total N	Organic-N	NH_4	NO_3	NO_2
					← mg N/liter →				
Field 4, inflow	95	38	16	147	1.02	0.94	0.04	0.02	0.02
outflow	92	34	28	138	2.31	2.17	0.05	0.06	0.03
Field 8, inflow	171	102	20	20	1.12	1.00	0.03	0.07	0.02
outflow	164	113	5	14	1.81	1.60	0.13	0.05	0.03
Field 14, inflow	144	95	13	18	1.08	1.02	0.00	0.04	0.02
outflow	222	139	9	18	1.95	1.85	0.07	0.05	0.05
Field 15, inflow	375	224	31	75	1.54	1.22	0.11	0.19	0.02
outflow	522	302	10	27	1.36	1.12	0.21	0.01	0.02
Average, all fields:									
inflow	235	144	22	44	1.19	1.05	0.05	0.08	0.02
outflow	332	199	11	23	1.86	1.69	0.12	0.04	0.03

Science, entitled "A Conceptual Nitrogen Model for Flooded Rice Culture," dated December, 1975.

Since it is not feasible to reproduce the more than 200 pages of Ms. Wagenet's thesis, only some of the N data for Fields 8 and 15 will be presented herein. Figure VIII-5 gives the inflow and outflow water flow rates, ranging from 0.02 to 0.05 cfs/ac and from nil to 0.008 cfs/ac, respectively. Figures VIII-6 through VIII-9 contain the concentrations of NO_3-N, NH_4-N, Organic-N, and Total N for the inflow and outflow waters. Total N and Organic-N were determined in filtered and unfiltered water samples. Field 8 received 100 lbs N/ac by aerial broadcast, and then incorporated before flooding. Shortly after flooding, both NH_4-N and NO_3-N in the outflow were highest. The NO_3-N in the inflow was high at day 142, and shortly thereafter. Of the Total N, Organic-N was the predominant N species throughout the season.

For Field 8, Table VIII-8 contains a compilation of the mass of N in the applied and runoff waters, the soil solution, and the soil itself. This and other data were used to develop the N inputs, outputs, and sinks and sources given in Figure VIII-10. The major inputs of N are from applied fertilizer and irrigation water, but by far the major source/sink of N is the native soil N pool. The outputs of N are almost equally divided among denitrification losses, seepage losses, and harvested grain. The mass of N in surface runoff is only about 14% of that N entering the field. Although the fertilizer N added to the soil is 3X and 4.6X that taken up by plant and the harvested grain respectively, nearly 1/3 was lost through denitrification and another 1/3 to seepage losses. Management of denitrification and seepage losses is difficult, and the losses are unavoidable. It appears that the most viable management approach is to increase the fertilizer use efficiency.

As mentioned previously, of the four rice fields only Field 15 received a top-dressing of N fertilizer due to the uncommonly cool growing season in

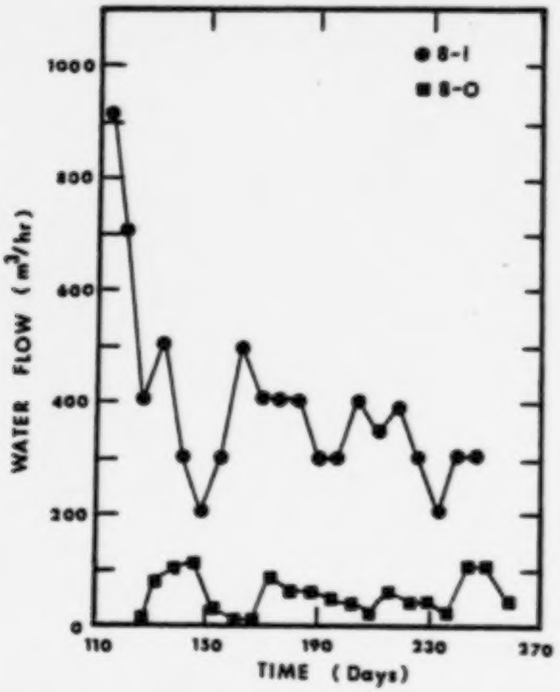


FIG. VIII-5: INFLOW (I) AND OUTFLOW (O) RATES (m³/hr) FOR FIELD NO. 8.
(m³/hr = 0 0098 cfs), Time In Julian Calender Days.

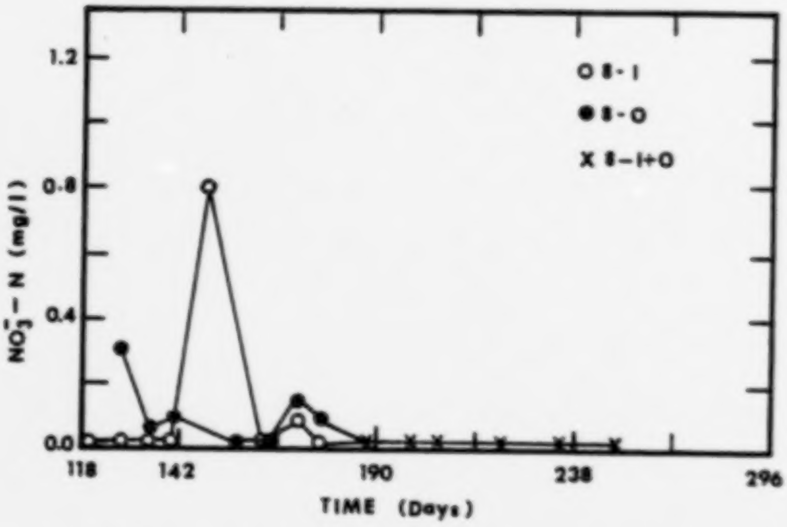


FIG. VIII-6: NITRATE-NITROGEN CONCENTRATION (mg/l) IN FLOOD WATER OF FIELD NO. 8.
(x Denotes Crossing Over Of Data Points)

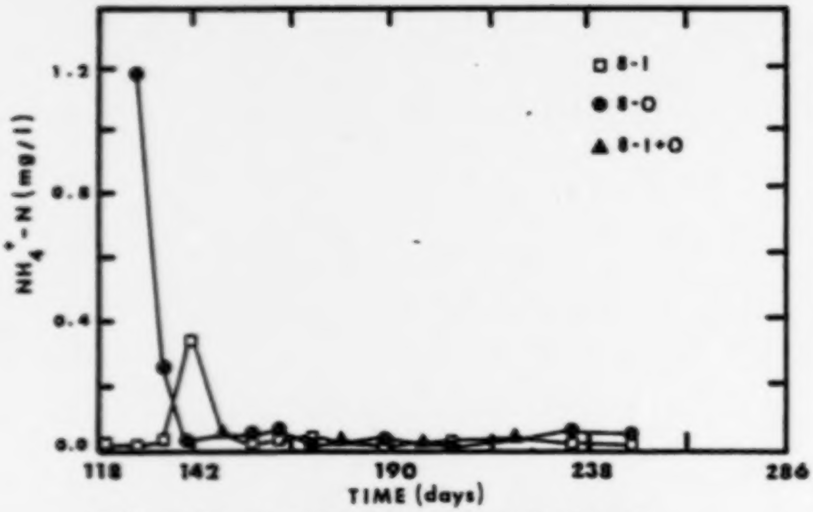


FIG. VIII-7: AMMONIUM-NITROGEN CONCENTRATION (mg/l) IN FLOOD WATER OF FIELD NO. 8.

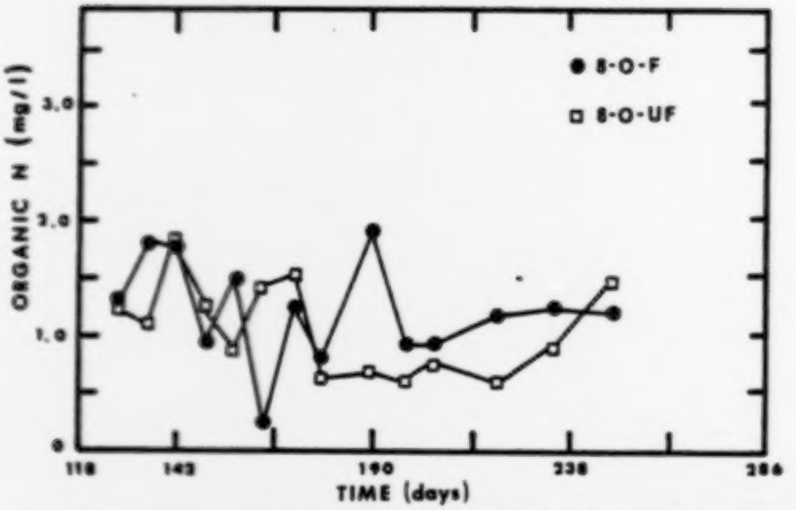


FIG. VIII-8: ORGANIC NITROGEN CONCENTRATION (mg/l) IN OUTFLOW FLOOD WATER FOR FILTERED (F) AND UNFILTERED (UF) SAMPLES OF FIELD NO. 8.

TABLE VIII-8

Summary of Mass Emissions of Nitrogen on Field no. 8

Component	kg N/day	kg N/season ‡	kg N/ha/season
INFLOW:			
Total N (UF)	12.6	1669	29.3
Total N (F)	10.6	1403	24.6
NO_3^--N	0.6	75.9	1.3
NH_4^+-N	0.5	63.2	1.1
Organic N	11.6	1530	26.9
SURFACE RUNOFF:			
Total N (UF)	1.7	245	4.3
Total N (F)	2.0	274	4.8
NO_3^--N	0.1	9.7	0.2
NH_4^+-N	0.2	24.7	0.4
Organic N	1.5	211	3.7
SOIL SOLUTION:			
Total N	1/	400	7.0
NO_3^--N	1/	162	2.8
NH_4^+-N	1/	87	1.5
Organic N	1/	152	2.7
SOIL POOL:			
Total N	1/	6.87×10^5	1.21×10^4
NO_3^--N	1/	1298	23
NH_4^+-N (sol)	1/	4305	76
NH_4^+-N (ads)	1/	9908	174
Organic N	1/	6.87×10^5	1.21×10^4

1/ Data from the soil samples cannot be interpreted to give values for quantities of nitrogen moving into or out of the soil each day; therefore, seasonal values are given and assumed to be constant.

‡ Length of season was 133 days.

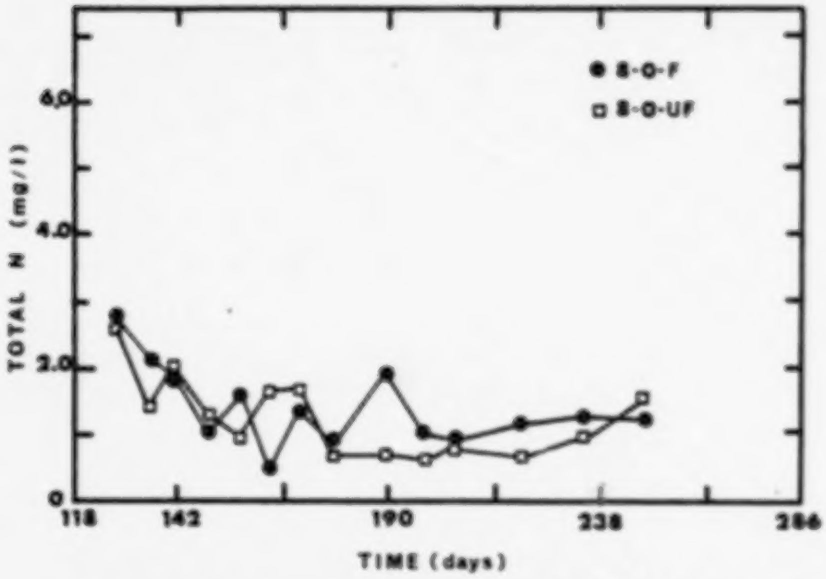


FIG VIII-9: TOTAL NITROGEN CONCENTRATIONS (mg/l) IN OUTFLOW FLOOD WATER FOR BOTH FILTERED (F) AND UNFILTERED (UF) SAMPLES OF FIELD NO. 8.

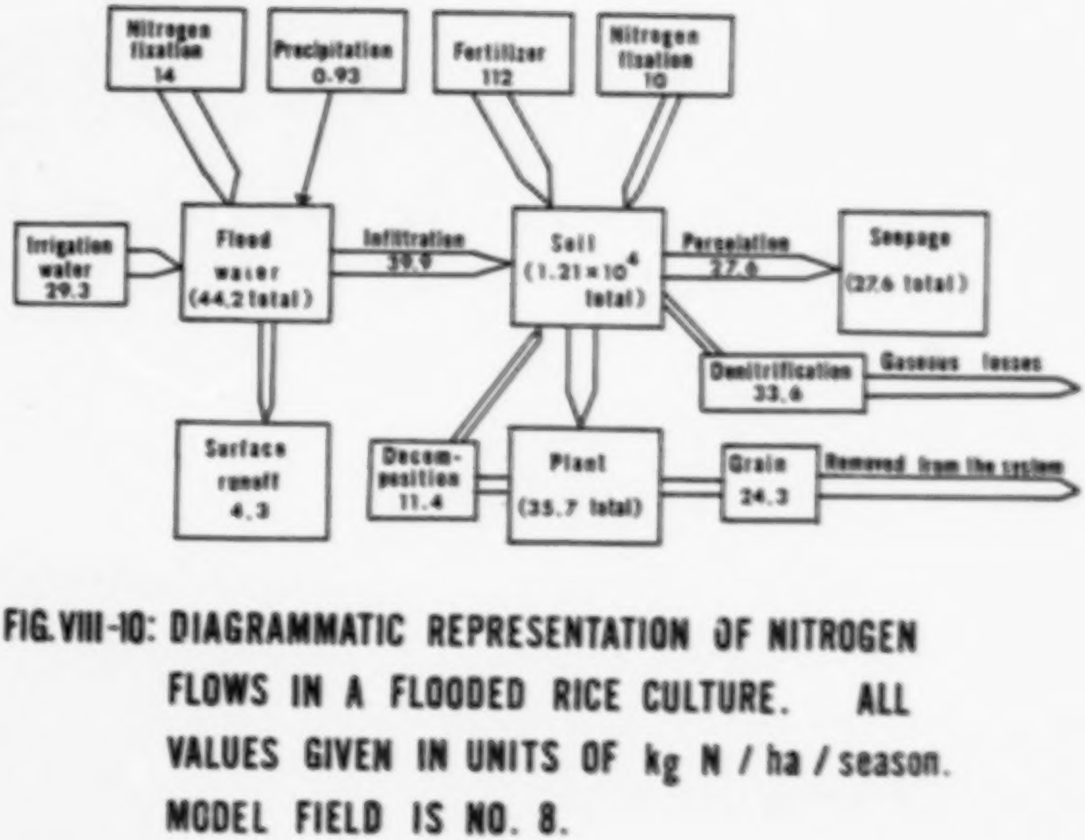

Nitrogen fixation 14
Precipitation 0.93
Fertilizer 112
Nitrogen fixation 10
Irrigation water 29.3
Flood water (44.2 total)
Infiltration 39.9
Soil (1.21×10^4 total)
Percolation 27.6
Seepage (27.6 total)
Denitrification 33.6
Gaseous losses
Surface runoff 4.3
Decom-position 11.4
Plant (35.7 total)
Grain 24.3
Removed from the system

FIG. VIII-10: DIAGRAMMATIC REPRESENTATION OF NITROGEN FLOWS IN A FLOODED RICE CULTURE. ALL VALUES GIVEN IN UNITS OF kg N / ha / season. MODEL FIELD IS NO. 8.

1975. Field 15 received 100 lbs N/ac as preplant in the form of $(NH_4)_2SO_4$ and N-aqua, in addition to 31 lbs N/ac $(NH_4)_2SO_4$ as top dressing. Figure VIII-11 shows a plot of NH_4-N and Total N concentration in the spill waters just prior to and immediately after aerial application of 35 kg N/ha. Water samples from Field 15 were collected on an hourly basis for two days with an ISCO Automatic Water Sampler, and extended to 3-hour intervals for three more days. Sample bottles were chilled with crushed ice during the sampling period, and transported in a cooler to the laboratory for analysis. This intensive sampling gave NO_3-N and NO_2-N concentrations that were consistently low, while the NH_4-N and Total N concentrations were significant. The fertilizer was applied on day 198 between 1000 and 1030 hrs, and the first sampling was taken at 1200 hrs of that day. The $(NH_4)_2SO_4$ fertilizer dissolved rapidly, and peak concentrations were reached about 20 hrs after application. Gradual decreases in N concentrations were noted, and levels of N decreased to normal levels within 5 days.

C. Colusa Basin Drain.

Colusa Basin Drainage Canal (Fig. VIII-3), a 70-mile canal, serves as a conveyor of return flows during the irrigation season and of flood runoffs during the nonirrigation season. This flow passes through the outfall gates (see inset for Fig. VIII-3) into the Sacramento River above Knights Landing, as well as through the Knights Landing Ridge Cut into the Yolo Bypass. The outfall gates are not opened when the water stage height in the Sacramento River is higher than the drain. This occurs during heavy storm runoffs and large reservoir releases during the winter months; normally from December through March. USGS gaging stations on the Colusa Basin Drain (CBD) are located at Highway 20 (CBD-3) and at the junction of Roads 99E and 108 (CBD-1). Flow data for these stations for 1975 irrigation season is given in Appendix Tables 36 and 37. For CBD-1 in

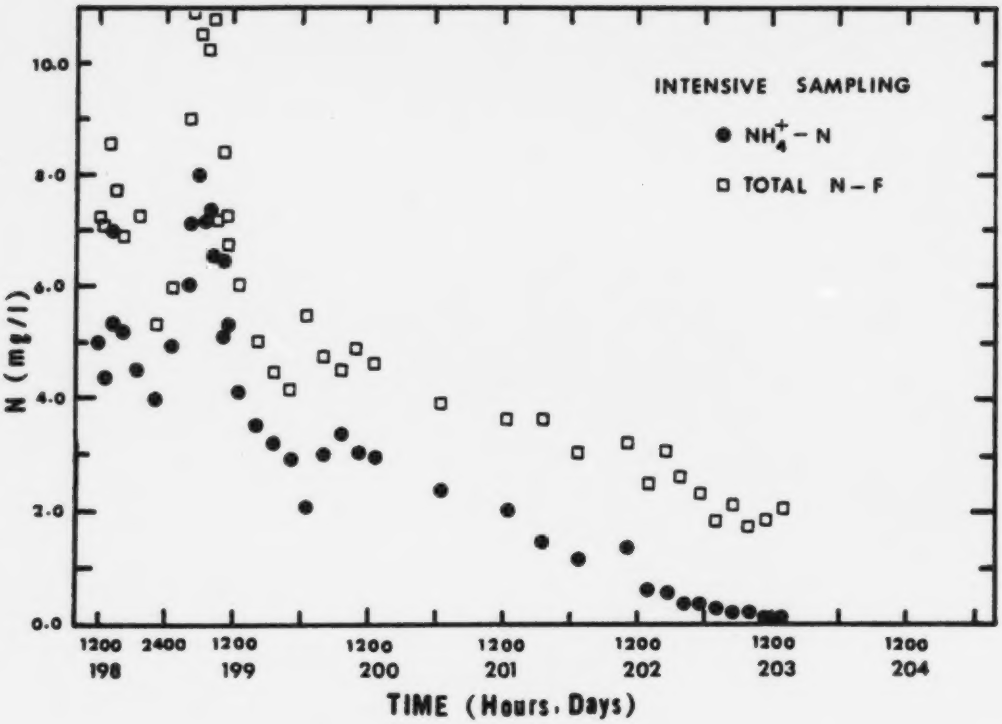


FIG. VIII–11: TOTAL N AND NH_4–N IN INTENSIVELY SAMPLED DRAIN WATERS, DURING AND AFTER 35 Kg N/ha TOP–DRESSING OF N FERTILIZER IN FIELD NO. 15

the 1974 hydrologic year (October, 1973 to September, 1974), the total flow was 461,308 ac-ft, of which nearly 60% occurred between April and September. The mean discharge was 637 cfs, with a minimum of 59 cfs and a maximum of 2,160 cfs.

Table VIII-9 gives the 1975 irrigation seasonal water quality data for five stations in the Colusa Basin Drain (Fig. VIII-3). For comparison purposes, GCID's supply water is also included in this table. The primary data for these stations are found in Appendix Table 36. As shown in Table VIII-9 there is a trend of increasing salinity and suspended matter in the drain from its headwaters to the Knights Landing area. This trend would be expected, since return flows are reused and discharged back into the drain. A recent California Department of Water Resources study in this study area points out that the downstream reuse of return flows results in a basin irrigation season efficiency of about 70% for the 1960-70 period. The quality of these return flows is nearly the same as the quality of the supply waters for the San Joaquin Valley Study area (Table VI-1).

Figures VIII-12 and VIII-13 show plots of EC and SS, respectively, for GCID supply water and two downstream stations on CBD. For CBD-1, the EC was highest in early April, when flows were generally lowest. EC also peaked in June and from late October to early November. In contrast, the peak SS concentration occurred in early September, when the rice fields were drained prior to harvest (coincidentally EC was low). CBD-1 was sampled frequently, and its water quality data are reported in Appendix Table 37. These plots indicate that, throughout the irrigation season, there are both temporal and spatial differences between stations.

Appendix Table 38 contains detailed water quality data for these Colusa Basin Drain stations for June and September, 1975. They reflect the integration of many lateral drain inputs, such as those given in Appendix Table 30.

Table VIII-9: The 1975 (April through October) Seasonal Water Quality in Several Reaches of the Colusa Basin Drain (CBD)

Station	Description	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)
D-14	GCID Supply Water	180	116	15	24
CBD-5 (D-5)	CBD at Sidds Road	315	187	16	31
CBD-4 (D-15)	CBD at Princeton Road	409	243	22	48
CBD-3 (D-12)	CBD at Colusa Bridge, Hwy 20	603	362	37	74
CBD-2	CBD at Davis Weir	651	379	46	78
CBD-1	CBD at Roads 99E and 108	721	427	66	111

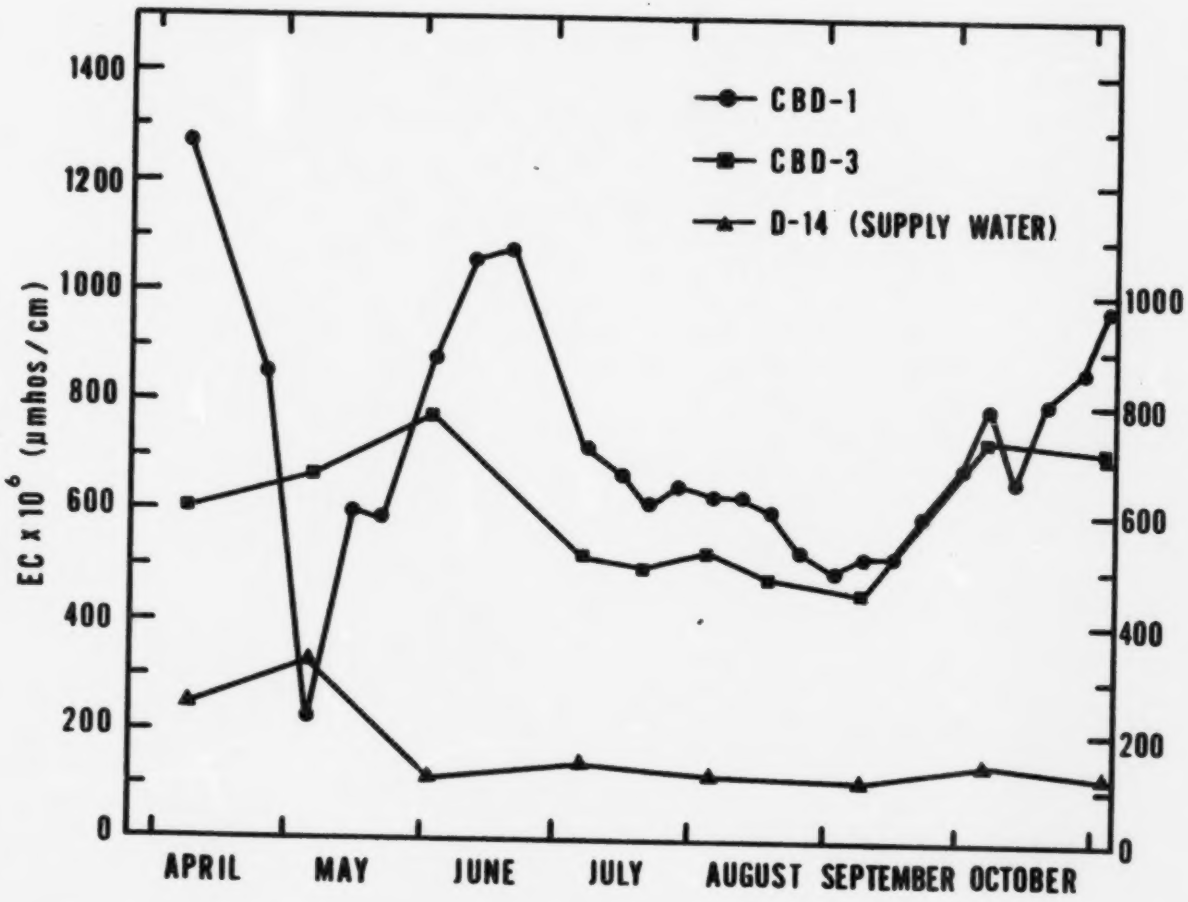


FIG. VIII-12: PLOT OF EC FOR STATIONS CBD-1, CBD-3, AND G.C.I.D. SUPPLY WATER (D-14) FOR 1975 IRRIGATION SEASON.

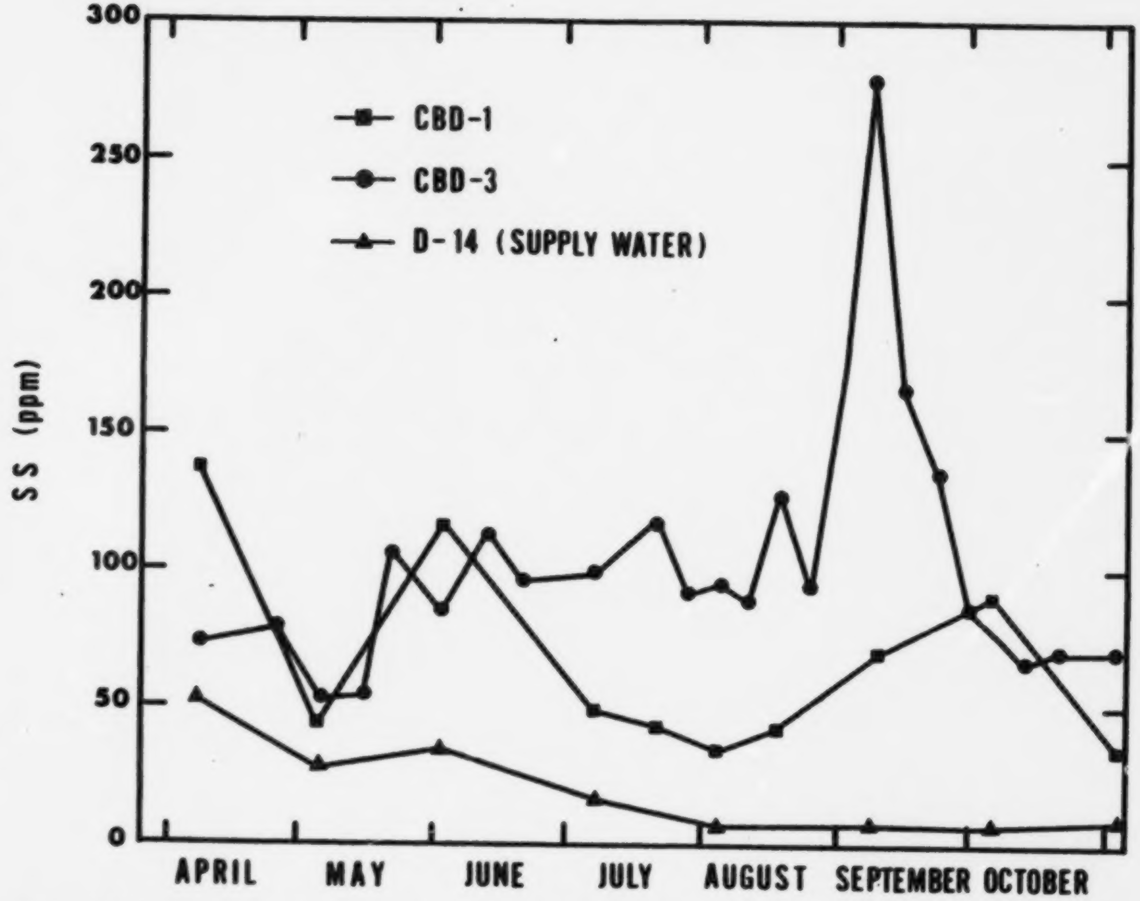


FIG. VIII-13: PLOT OF SS FOR STATIONS CBD-1, CBD-3, AND G.C.I.D. SUPPLY WATER (D-14) FOR 1975 IRRIGATION SEASON.

Since CBD represents an internal discharge station for the NPDES permittee in the Sacramento Valley, the relations between EC and TDS, and turbidity and SS, were determined. Figure VIII-14 shows a plot of the salinity parameters. TDS and EC are highly correlated, with an r-value of 0.986. Figure VIII-15 contains a plot of the suspended matter parameters. SS is not as well correlated to turbidity (r = 0.79) as are the salinity parameters.

The major water quality problem in the Colusa Basin Drain appears to be the sediment load, since it is high relative to the Sacramento River, and is noticeable as a plume at the outfall near Knights Landing. The reason(s) why there is such a high suspended sediment load, in spite of the decreased water flow velocity in the lower reaches of Colusa Basin Drain, is not obvious.

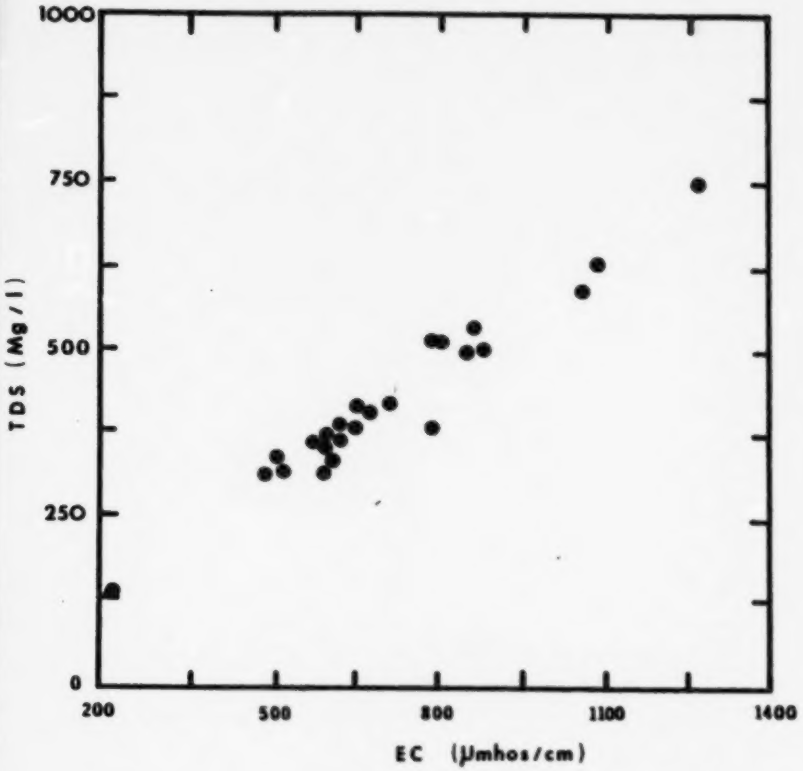


FIG. VIII-14: RELATION BETWEEN TDS AND EC FOR STATION CBD-1 IN 1975.

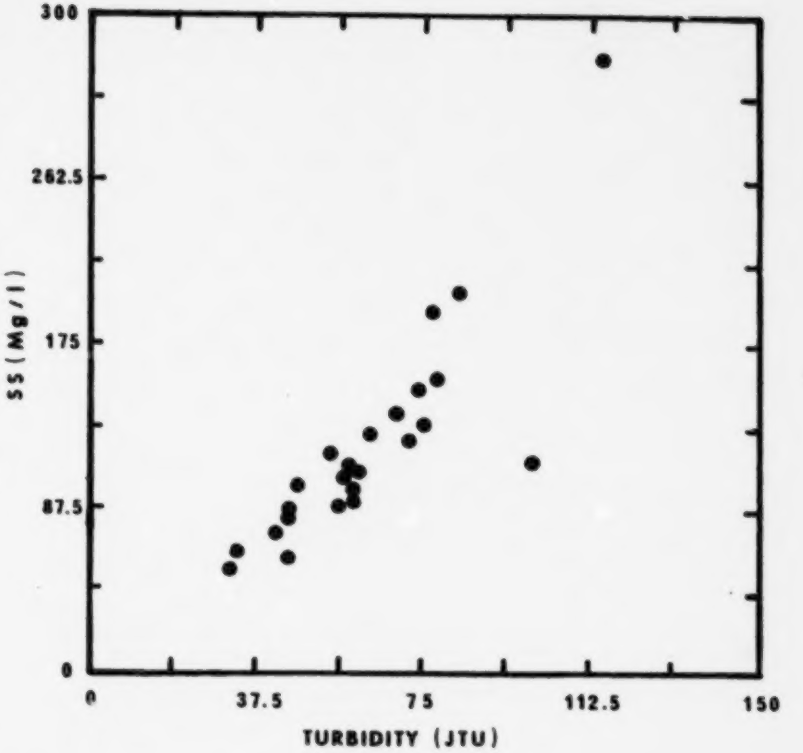


FIG. VIII-15: RELATION BETWEEN SS AND TURBIDITY FOR STATION CBD-1 IN 1975.

IX. TOUR OF FIELD STUDY SITES

A tour of the field study sites was held in October, 1975. Project cooperators and collaborators assisted in the conduct of the tour. An itinerary is found in Table IX-1. Since the 1975 irrigation season was over at many sites, this tour focused in on the vast irrigation return network and the extensive return flow use areas. These reuse areas include the grassland and wildlife habitats, as well as downstream water districts in the Mendota-Crows Landing Return Flow Group. In addition to the Colusa Basin Drain in the Sacramento Valley, the supply and drainage network and a rice field were visited in Glenn-Colusa Irrigation District. A total of 29 participated in the San Joaquin Valley tour while 23 participated in the Sacramento Valley field locations. A roster of participants is found in Table IX-2, representing diverse interests.

Table IX-1: Irrigation Tailwater Management Field Tour

October 23-24, 1975

Oct. 23	8:00-9:30 am	Convene at Central California Irrigation District Office, 1335 West I Street, Los Banos
	8:00 am	Introductions, hand out maps
	8:10 am	San Joaquin River, McIntyre
	8:20 am	NPDES Permit, Mendota-Crows Landing Return Flow Group, Bates-McCullough
	8:40 am	EPA Field Studies, Tanji-Iqbal
	9:10 am	Ongoing EPA Irrigation Return Flow Projects, Hornsby
	9:20 am	Open for Discussion
	9:30 am	Depart for Field Tour
	9:45-11:00 am	Los Banos Wildlife Area, Cawthon-Connelly/Tanji-Iqbal
	11:15-11:45 am	Turner Island District Intake, Pfitzer/Iqbal
	12:00-1:00 pm	Lunch at Ponderosa Restaurant in Los Banos
	1:00-1:45 pm	Grasslands Water District and Camp 13 Slough, Cook
	2:00-3:45 pm	Panoche Water District, Ram/Iqbal-Tanji
	4:00-4:30 pm	Broadview Water District, Durrenberger/Iqbal-Tanji
	4:30 pm	Depart for Davis. Enroute dinner at Ye Olde Hoosier Inn in Stockton
	---- pm	Housing in Davis, University Lodge (916-756-7890) or Voyager Inn (916-756-2200)
Oct. 24	7:30 am	Depart Davis for Willows
	9:00-10:00 am	Convene at Glenn-Colusa Irrigation District Office, 344 E. Laurel, Willows
	9:00 am	Introductions, hand out maps
	9:10 am	GCID Water Measurement Program, Haapala-Clark
	9:25 am	EPA Field Studies, Tanji-Van De Pol
	9:40 am	Colusa Basin Drain, Clawson
	9:50 am	Open for Discussion
	10:00 am	Depart for Field Tour Rice Fields, Haapala/Van De Pol-Wagenet Distribution System and Drain Laterals, Haapala/Van De Pol
	12:30-1:30 pm	Lunch at Blue Gum
	1:30 pm	Depart for Colusa Basin Drain
	2:45-3:30 pm	Colusa Basin Drain Outfall near Knights Landing, Tanji
	3:30 pm	Return to Davis/Sacramento Airport/etc.

Table IX-2. IRRIGATION TAILWATER MANAGEMENT FIELD TOUR

Reproduced from best available copy.

NAME	TITLE	ORGANIZATION AND LOCATION	TELEPHONE	LOS BANOS 10/23/75	WILLOWS 10/24/75
Dr. Khaled E. Aref	Senior Land & Water Resources Specialist	SWRCB - Sacramento, CA.	(916) 322-4566	✓	
C. V. Bates	Manager-Secretary, Return Flow Group Coordinator	CCID - Los Banos, CA.	(209) 826-1621	✓	
Dr. James W. Biggar	Professor of Water Science & Water Scientist	LAWR - Univ. of Calif., Davis, CA.	(916) 752-0491	✓	
David Cahoon	Assistant Water Resources Engineer	DWR - Red Bluff, CA	(916) 527-6530		✓
Robert Clark	Manager-Secretary	GCID - Willows, CA.	(916) 934-4695		✓
Robert Clawson	Chief, Water Quality & Biology Unit	DWR - Red Bluff, CA.	(916) 527-6530		✓
Sam Cook	Watermaster	CCID - Los Banos, CA.	(209) 826-5136	✓	
Marshall English	Graduate Student	Ag. Econ. - Univ. of Calif., Davis, CA.	(916) 756-5013	✓	
Joseph Fitz	Graduate Student	Ag. Econ. - Univ. of Calif., Davis, CA.	(916) 752-1533	✓	✓
Richard Haapala	District Engineer	GCID - Willows, CA.	(916) 934-4695		✓
Jack Hodges	Sanitary Engineering Associate	SWRCB - Sacramento, CA.	(916) 322-6653	✓	✓
Dr. Gerald Horner	Lecturer and Agricultural Economist	USDA-ERS - Davis, CA.	(916) 752-6001	✓	✓
Dr. Arthur G. Hornsby	Project Officer	USEPA - Ada, OK.	(405) 332-8800	✓	✓
Steve Green	Assistant Land & Water Use Analyst	RWQCB - Fresno, CA.	(209) 488-5116	✓	
Muhammad M. Iqbal	Jr. Development Engineer	LAWR - Univ. of Calif., Davis, CA.	(916) 752-0493	✓	✓
William R. Johnston	Director	S.J.V. Interagency Drainage Program - Fresno, CA.	(209) 488-5681	✓	
D. E. Kienlen	Return Flow Group Chairman	Sac. Valley Water Quality,Committee - Sacramento, CA.	(916) 443-2593		✓
William Kincey	Research Assistant	Ag. Econ. - Univ. of Calif., Davis, CA.	(916) 752-0213	✓	✓
Dick Lallatin	Water Resources Engineering Associate	DWR - Red Bluff, CA.	(916) 527-6530		✓
S. MacGillivray	Associate Land & Water Analyst	DWR - Bakersfield, CA.	(805) 323-7506	✓	✓
A. F. McCollam	Manager-Secretary	Sac. Valley Water Quality Committee - Sacramento, CA.	(916) 446-0197		✓
T. R. McCullough	Assistant Manager	CCID - Los Banos, CA.	(209) 826-1421	✓	
Victor McIntyre	Chief, Water Quality Unit	DWR - Fresno, CA.	(209) 492-5272	✓	
Michael Miller	Biologist	U.S. Fish & Wildlife Service, Sacramento, CA.	(916) 484-2049	✓	
Robert Miller	Agricultural Engineer	SCS/SWRCB - Sacramento, CA.	(916) 322-9655	✓	
George Mullen	Visiting Professor of Soil Physics	LAWR - Univ. of Calif., Davis, CA	(916) 752-4910	✓	✓
Robert Pfitzer	Assistant General Superintendent	CCID - Los Banos, CA.	(209) 826-1421	✓	
Ann Quek	Staff Research Associate	LAWR - Univ. of Calif., Davis, CA.	(916) 752-6947		✓
Roger Robb	Water Management Specialist	USDA-SCS, Davis, CA.	(916) 758-2200	✓	✓
Walter Ryley	Assistant Land & Water Use Analyst	RWQCB - Sacramento, CA.	(916) 452-3977	✓	✓
Rudy Schnagl	Graduate Student	LAWR - Univ. of Calif., Davis, CA.	(916) 756-7325	✓	
Herbert Schulbach	Soil & Water Area Specialist	UC-AES - Colusa, CA.	(916) 458-2105	✓	✓
Kenneth K. Tanji	Lecturer & Associate Water Scientist	LAWR - Univ. of Calif., Davis, CA.	(916) 752-0683	✓	✓
Ronald M. Van De Pol	Postgraduate Research Water Scientist	LAWR - Univ. of Calif., Davis, CA.	(916) 752-0693	✓	✓
Linda Wagenet	Research Assistant	LAWR - Univ. of Calif., Davis, CA.	(916) 758-4469	✓	✓
David Wolfe	Staff Research Associate	LAWR - Univ. of Calif., (USFS), Fresno, CA.	(209) 894-2411	✓	✓
Henry B. Wolfsen	Rancher, Board Member	CCID - Los Banos, CA.	(209) 392-2265	✓	

SWRCB = State Water Resources Control Board
RWQCB = Regional Water Quality Control Board
CCID = Central California Irrigation District
GCID = Glenn-Colusa Irrigation District
DWR = Department of Water Resources
SCS = Soil Conservation Service
ERS = Economic Research Service
EPA = Environmental Protection Agency
LAWR = Department of Land, Air and Water Resources
AES = Cooperative (Agricultural) Extension Service

X. THE ECONOMIC FEASIBILITY OF RECYCLING DRAINAGE WATER

The economic feasibility of drainage recycle systems is unknown. Therefore, an analysis to determine the least cost combination of irrigation water, labor, capital, and (return-flow) management for irrigated farms in the selected study areas is being conducted. Because there are differences in the scale of operations and the type of water quality problems present among different units within the two study areas, several separate analyses are required.

In the San Joaquin Valley study area, the major water quality problem associated with irrigation return-flows is salinity and boron. These return-flows are composed of both a surface and a subsurface component. The subsurface component is characterized by a high concentration of dissolved salts, and most notably boron, which is highly toxic to crops.

Because irrigation water is relatively expensive to some users in the area, these users have been recycling return-flows for several years, both at the farm level and the irrigation district level. Three different sizes of recycle systems are in operation for the study area -- a 170-acre field recycle system, a 1,675-acre farm recycle system, and the large-scale system which has been in operation in the Broadview Water District. Economic models of these three systems have been developed, in order to determine the least cost combination of inputs under a range of policy alternatives.

The analysis of the field system is essentially an engineering cost study, supplemented by data from a system which is currently operating on a field in the Panoche District.

The model being developed for the 1,675-acre farm is a linear programming (LP) analysis based on an actual farm, also located in the Panoche District. The objective of the LP program is to determine the effects on the profitability and the cropping pattern of alternative institutional constraints on return-flow discharge. The model maximizes net returns to land and management, subject to constraints on resource availability, crop rotation, crop tolerance to salts, return-flow production, and discharge limits.

Since the farm collects subsurface water in a tile drainage system, return-flows are highly saline, and must be diluted with district water before reuse. To allow for the possibility of declining yields due to salt buildup in the soil, a multi-period LP model is appropriate. This type of model allows for changes in the input-output coefficients in one period, depending on the nature of the activities in the preceding periods. The technical coefficients and prices used in the model are taken from the actual farm being modeled.

The results of the analysis will provide a way of measuring the effect of discharge requirements on a farm in this area.

The model for the districtwide system is also a multi-period LP problem, with similar constraints. The coefficients for this model are derived from data obtained from the Broadview District, and thus reflect the costs and economies associated with the larger scale of operation.

The Sacramento River Valley study area is characterized by a different set of conditions than those obtained in the San Joaquin. Glenn-Colusa Irrigation District (GCID) has a relatively abundant, inexpensive, and high-quality supply of water. The major source of concern about irrigation return-flows in this area is their high concentration of sediment. Since rice usually accounts for about two-thirds of the irrigated acreage of the district, an LP model is not appropriate.

Most of the rice acreage in California is concentrated in the Sacramento River Valley area, and is grown under conditions similar to those in the GCID. Therefore, any policy that causes a significant change in rice acreage in GCID is likely to induce proportionate changes in total California rice acreage. Since the California rice sector faces a downward-sloping demand curve, the price of California rice is influenced by the quantity grown in the State. Thus, it is assumed that the price of GCID growers get for their rice is a function of the quantity they produce.

In order to account for this economic specification, a quadratic programming model has been developed. Using an adjusted statewide demand curve for California rice, the model allows the price to change with the quantity produced. The model will choose the optimum level of crop, discharge, and recycle activities that will maximize net returns to land and management, subject to the physical and institutional constraints imposed.

A. Field Recycle Systems

The economic costs of requiring field tailwater reuse systems and pressurized irrigation water delivery systems to minimize runoff should be estimated and compared with alternative control options. Field recycle systems are possible where locational, physical, or institutional conditions do not permit farm or district reuse systems. Tailwater can be eliminated within a field by a recycle system or by utilizing irrigation water delivery systems that are highly efficient in water applications. Both of these options involve investments in equipment and facilities that will probably reduce the use of labor and irrigation water.

The rate which capital investment substitutes for labor and irrigation water in the production process and the relative costs of resources will determine the least-cost system to eliminate tailwater. Changes in the marginal rate of resource substitution will also result from the size of field as economies of size exist in some irrigation recycle equipment. Other physical factors such as the quality of water and the productivity and the type of soil also affect the determination of the least-cost irrigation and recycle system.

Objectives

The objectives of this study are: (1) to estimate the marginal rate of substitution of labor, irrigation water, and capital in irrigation and recycle systems and (2) to determine the least-cost irrigation and recycle system to eliminate the tailwater discharge from a San Joaquin Valley field.

Procedure

The marginal rate of substitution of factor inputs will be statistically estimated from engineering data on five irrigation and tailwater recycle systems. Specifications, costs, and labor input coefficients will be derived from engineers, irrigation specialists, and retail equipment dealers. Current Agricultural Extension crop production budgets will also be used as a guide in developing these data.

The amount and quality of irrigation water applied to 170-acre field of tomatoes and captured by a recycle system was monitored in 1975. The field will again be monitored in 1976. These estimates of water use and recycle efficiencies will be utilized to determine the effectiveness of the system. Presently, the field is being irrigated by unlined ditches and siphon systems that have low capital requirements, high labor requirements, and low water use efficiency.

An irrigation system using gated pipe would increase the water use efficiency, require more capital and less labor, but a recycle system would be required to eliminate tailwater. Preliminary budgets were prepared for the present system with no tailwater recycle system and for a gated pipe distribution system with provisions for recycling the tailwater. These costs are presented in the following tables with diagrams of systems' physical dimensions for 160-acre, 320-acre, and 640-acre fields.

Three additional cost budgets for pressurized irrigation systems will be completed in some manner and statistical estimates of the marginal rates of substitution will be completed next year.

Table X-1:

Annual Per Acre Costs of Irrigating 160 Acres
of Tomatoes with an Open Ditch System,
Panoche Water District, 1975

Item	Dollars per acre
Operating Costs	
Ditch Open and Close	
Labor (.12 hr.)	.36
Fuel & repair	.82
Irrigation	
Labor ($2.75/hr.)	41.25
Water ($6.00/acre)	42.00
Miscellaneous	.33
Total Operating Costs	84.76
Depreciation	
Ditcher, 54", $2,100, 20-yr. life	.13
Siphons, 1-1/2" - 300' $475, 10-yr. life	.14
Canvas, 12 pcs., $350, 5-yr. life	.20
Ditch closer, $2,200, 15-yr. life	.18
Total Depreciation	.65
Interest on Investment @ 8%	
Ditcher	.11
Siphons	.05
Canvas	.04
Ditcher closer	.11
Total Interest on Investment	.31
TOTAL COST OF IRRIGATION	85.72

Table X-2:

Annual Per Acre Cost of Irrigating 160, 320, and 640 Acres of Tomatoes, With Gated Pipe and Recycle System, Panoche Water District, 1975

Item	160 acres		320 acres		640 acres	
		cost/ acre		cost/ acre		cost/ acre
Operating Costs						
Irrigation						
Labor ($2.75/hr.)		27.50		27.50		27.50
Water ($6.00/acre)		30.60		30.60		30.60
Recirculation pump power		3.12		3.12		3.12
Gated Pipe Installation						
Fuel		.34		.75		.75
Labor		.34		.34		.34
Total Operating Costs		61.90		62.72		62.72
	Total cost		Total cost		Total cost	
Depreciation						
PVC Pipes						
15" 30-yr. life	10,560	2.20	21,120	2.20	47,520	2.46
10" or 12" 30-yr. life	3,330	.70	3,960	.40	7,920	.40
Gated Pipes 8" & 10" 30-yr. life	18,744	3.90	18,744	2.00	37,488	2.00
Pump 10-yr. life	4,000	2.50	5,500	1.70	5,500	.90
Settling Pond 30-yr. life	3,250	.67	3,250	.30	5,000	.27
Tractor 4-yr. life	2,000	.02	2,000	.04	2,000	.04
Trailer 6-yr. life	1,200	.01	1,200	.02	1,200	.02
Total Depreciation Cost		10.00		6.66		6.09
Interest on Investment @ 8%						
PVC Pipes 15"		2.64		2.64		2.96
PVC Pipes 10" or 12"		.84		.48		.48
Gated Pipes		4.68		2.36		2.36
Pump		1.00		.68		.36
Settling Pond		.80		.40		.32
Tractor		.01		.01		.01
Trailer		.01		.01		.01
Total Interest Cost		9.98		6.58		6.50
TOTAL COST OF IRRIGATION		81.88		75.96		75.31

B. A Farm Recycle System

The purpose of this study is to examine the effects on profitability and cropping patterns on the 1,675-acre tile-drained farm in the Central San Joaquin Valley under a range of constraints on the discharge and irrigation return-flows.

Description of the Model

The preliminary model is based on data for the period 1969 to 1974. This farm has been recycling some of its return-flows since 1956, and its size is such that the assumptions of perfect competition and constant returns to scale can be made. The initial approach is to develop an LP analysis in which there are no constraints on the discharge of the water collected by subsurface tiles, and then to see how these results differ when we constrain the discharge. The model attempts to maximize net returns to land and management, subject to the appropriate technical and institutional constraints.

The tile-drained farm is a 1,675-acre, irrigated, contiguous parcel of land. They grow a fairly balanced mixture of processing tomatoes, cotton, alfalfa, and wheat or barley. During the 1960's, the water table in this region rose steadily to the point where, in 1969, tile drainage was installed on the lower end of the farm, at a depth of 7 feet. This was required in order to drain the root zone and allow normal yields. Since that time, certain areas of the farm that were not being drained directly were still subject to yield reductions, so in 1975, the system was expanded to cover the whole farm.

The farm has three sources of water. Its entitlement from the Panoche Water District is approximately 5,025 acre-feet, at a cost (1974) of $7.11 per acre-foot at the head gate. Hammond Drain, which carries surface runoff, and probably subsurface seepage from the uphill land directly to the south of the farm, goes through the property, and discharges into the Panoche Drain (Fig. VII-10). The water pumped from the tile sumps and the on-farm surface returnflows from this tile-drained farm also empty into Panoche Drain. At the lowest corner of the farm, these waters flow out into the Russell Drain, some of which is pumped back into the farm's irrigation system at PWD-10E, where it can be reused directly or mixed with district supply water.

Eight cropping alternatives and six sources of water are defined in the model. Prices and the amount of land requiring drainage varied over time. Initially an annual uniform increase of 300 acres of land needing drainage was assumed. The historical cropping pattern was duplicated in the model solution to estimate the quantity of water and use and resulting drainage water. Increases in water applications were assumed to offset yield reductions caused by increases in salt concentration. However, the amount of subsurface drainage water reused as irrigation water is limited by quality constraints imposed on the mixing of subsurface waters with water from the better quality sources. These limits are based on preliminary sampling of the water quality from these various sources.

Net returns were computed from actual gross returns for the period, net of sample production costs for the relevant crops in the central San Joaquin. Sample costs are net of water charges, land rent or interest and taxes, and management, since water costs are subtracted from the objective function whenever the relevant water activity is included in the basis at a positive level. Water prices are the sum of purchase price (for district water) and estimated pumping costs.

Preliminary Results

To maximize profits, all of the subsurface drainage water is reused in every period and maximum amounts of water from the Hammond Drain is also used. In the last period considered in the model, more low quality water could be used. However, this condition may be very sensitive to price changes. This indicates that if the supply of drainage water for reuse were reduced, significant reductions in acreage of salt tolerant crops could occur.

Planned Extension of Research

The cropping pattern derived in the model differs from actual farm activities because of agronomic and institutional constraints. These will be better identified in subsequent models.

If irrigation return-flow discharges are limited, then the flow in Hammond and Panoche Drains will be significantly reduced, and its quality will change. Further analysis should look at the system under varying conditions of water availability and water quality of this source. In addition, constraints on the discharge of on-farm return-flows will be imposed, to evaluate the economic effect of such policies on this farm.

Additional data on the water quality of these return-flows, the operation costs of the recycling system, and the relationship between yields and quality of applied irrigation water will be incorporated in order to give the model more flexibility.

C. The Effect of Alternative Irrigation Return-Flow Policies on Glenn-Colusa Irrigation District

A number of researchers have posited that an efficient pollution control policy would be to levy a tax on return-flows, corresponding to the marginal social cost of keeping the quality of the water body at or above some standard.[1] Policy makers have not accepted this alternative, and there is still considerable controversy about its applicability. This model attempts to provide an analysis of the economic effects of alternative policies on a subarea of the Sacramento River Valley, specifically, and the Glenn-Colusa Irrigation District. It is hoped that such an analysis will give policy makers more information on which to base their choice among alternative policies.

A quadratic programming (QP) approach was used to analyze the agricultural sector of the Glenn-Colusa Irrigation District. The model maximizes net returns to land and management, subject to a set of linear constraints on the use of certain fixed resources. Specifically, the problem is to:

$$\text{Maximize } Z = \hat{c}' \cdot \hat{x} - 1/2\ \hat{x}'\ Q\hat{x}$$

Subject to: $A\hat{x} \le \hat{b}$, $\quad \hat{x} \ge 0$, where

c and x are (nxl) vectors representing the prices per unit and the level of operation, respectively, of the firm's n activities; Q is an (nxn) symmetric matrix, A is an (mxn) matrix, and b is an (mxl) vector of quantities of the firm's m fixed resources. A global optimum solution is guaranteed if the constraint set is convex if Q is positive definite.[2]

A quadratic objective function results from the assumption that the "firm" in the model faces a downward sloping, linear demand curve for its products,

$$\hat{p} = \hat{c} - Q\hat{x}$$

Then the objective function is a total revenue function given by,

$$TR = \hat{p}' \cdot \hat{x} = (\hat{c} - Q\hat{x}) \cdot \hat{x} = \hat{c}' \cdot \hat{x} - \hat{x}'Q\hat{x}.$$

This function is maximized at the point where marginal revenue (MR) equals marginal cost (MC). Now,

$$MR = \frac{\partial(TR)}{\partial x'} = \hat{c} - 2Q\hat{x}, \text{ and } MC = A'y, \text{ where the elements of y are the}$$

variables of the associated dual problem:

$$\text{Min } \hat{b}' \cdot \hat{y} + \hat{x}' Q\hat{x}$$

$$\text{Subject to} \quad A'\hat{y} \geq \hat{c} - 2Q\hat{x},$$

$$\text{and} \quad \hat{y} \geq 0$$

A column of the matrix A gives the per unit input requirements of the associated activity, in terms of the firm's fixed resources. The dual variable, y_i, gives the marginal imputed value of resource i to the firm. Thus A'y is the vector of marginal activity costs; i.e., each element of A'y is the imputed marginal cost of some activity, in terms of the firm's fixed resources.

Since a competitive industry produces the quantity of output such that marginal activity cost equals average revenue (i.e., price of the product), we can model such an industry by modifying the estimated demand function such that its slope is one-half of the original, so that

$$p = c - 1/2\ Qx$$

$$TR = c' \cdot x - 1/2\ x'\ Qx,$$

$$\text{and } MR = c - Qx$$

Thus, the QP model then equates marginal cost to the modified marginal revenue, which is really the original average revenue equation given above. Since variable costs are included in the price intercept, c, the model will maximize net returns to land and management, subject to the institutional and physical constraints imposed.

Implementation of the Model

The Glenn-Colusa Irrigation District grows about 20 percent of the rice grown in California. In a sense, it serves as a proxy for statewide production of rice, in that most of the rice grown in California is produced in the

Sacramento Valley under quite similar conditions. Since California rice does not compete directly with rice grown in other parts of the country, the downward-sloping output demand function is appropriate to the extent that this district does represent statewide conditions on rice production. In addition, the district has the long-run option, under alternative constraints on water use and discharge allowed, of increasing its present capacity to recycle its irrigation return-flows. The long-run total cost function for increasing the recycling capacity of the district closely approximates a quadratic function. Thus, the variable cost of an increased recycling activity fits appropriately into the quadratic objective function.

The objective of this study is to determine how the Glenn-Colusa District, and by inference, the rice industry of California, will react to either a set of taxes or a set of limits on sediment-loaded return-flows, given that it will attempt to maximize its revenues subject to its technological and resource constraints.

In order to represent the alternative technologies available to the district growers, the model includes a set of production activities which produce three different crops under a variety of input combinations. Two irrigation methods and one alternative sediment-reducing technology are available for the three crops. A total of nine crop-producing activities are available, which in turn produce nine alternative quantity-quality ratios in their return-flows. These return-flows are represented by two return-flow discharge activities, one with high sediment load, and one with a low sediment concentration. In addition, a recycling activity is included with an upward-sloping marginal cost curve. Finally, two selling activities transfer the production of eight of the production activities into revenue.

The specific crops used in this model are rice, feed grain, and pasture. It is assumed that demand for pasture is perfectly elastic, only one irrigation method is used, and that it produces the same quality of return-flow regardless of technology. Thus, only one activity is incorporated to represent this crop, and it is a revenue-producing activity rather than a transfer activity. The eight production activities are "priced" at their variable cost per acre, with quadratic elements set to zero. Assuming constant yields per acre for each activity, their production is transferred to the selling activities in hundredweight units. The prices for the selling activities represent the modified demand curves for rice and feed grain in California. These demand curves were derived from those estimated by Adams.[4/]

The return-flow activities were "priced", or taxed at rates corresponding to their relative qualities. The absolute level of tax rates was varied over a range of values in order to see how the system would react under alternative assumptions about the social cost of discharging sediment-laden waters. These social costs are related to the effect on nonagricultural activities that suspended sediments may produce.

Two crucial assumptions are implicit in the way in which return-flows are reused in the model. The first, and the easiest to defend, is that the sediment-quality of water used in irrigation has no effect on the productivity of that water as an input, so that recycled water is a perfect substitute for freshwater in agricultural uses. The second assumption is that the quality of return-flows produced by a given activity is invariant with respect to the quality of the water diverted to that activity. This assumption is not justified in all cases, but on the average, it is probably valid. To assume otherwise would introduce a cyclical indeterminancy to the problem. No specific quality of return-flows could be specified, since it would depend on the ratio of freshwater to recycled water used. The quality of the recycled water is of course determined by the quality of the return-flows. Thus, it would be impossible to specify the absolute level of sediment load in any set of return-flows, and therefore, no meaningful tax would be levied.

The constraints of the problem are of three types: (1) resource availability, (2) upper and lower bounds on cropping rotations, and (3) constraints which relate the production activities to the return-flow and recycle activities.

Preliminary Results and Further Research

Preliminary runs were made with tentative estimates on the cost and effectiveness of alternative technologies, and without including transaction costs. An expanded model will attempt to incorporate more accurate information on relevant technologies, as well as transaction costs internal to the irrigation district, such as costs of enforcing control technologies, or monitoring return-flows.

The most interesting aspect of the set of solutions obtained under different levels of return-flow tax rate, is that additional recycling does not appear at a positive level until the tax is equal to $25.00 per acre-foot on the better quality return-flow activity. In other words, demand for water is not sufficient to encourage recycling until the tax rate is high relative to the price of water. A large settling basin could probably be built and maintained at less than $25.00 per acre-foot of water discharged.

This implies that a policy of setting discharge limits, as now authorized, would force the district to recycle its return-flows at a cost possibly greater than the cost of reducing the sediment load by secondary treatment. Thus, the limit policy may not allow for the more economically efficient solution, and would incur a higher social cost as a result.

Conclusions

If information is available on the cost of secondary treatment of return-flows, prior to their discharge back into the Sacramento River, then an optimal tax rate could be determined. Given this optimal tax rate and the actual limits to be imposed under the alternative policy, direct comparisons could be made between the solutions under these two policies. If all costs have been internalized to the District, then the optimal policy is the one which achieves some target level of sediment concentration in the Sacramento River at least social cost. That is, since we obtain a competitive market equilibrium, the solution at a higher level of output and revenue is preferred to the solution with less, since we are achieving the same level of water quality at a lower cost.

The comparison of these two policies should be done under several sets of alternative assumptions on the effectiveness of certain technologies and on prices, in order to ascertain the sensitivity of these comparisons to the relevant assumptions.

References

1. Baumol, W.J., and Oates, W.E., "The Uses of Standards and Prices for Protection of the Environment," The Swedish Journal of Economics, Vol. 73, No. 1, March 1971.

2. Hadley, G., Nonlinear Programming, Addison-Wesley, 1964.

3. Paris, Quirino, New Economic Interpretations of Linear Complementarity Problems and Extensions, unpublished manuscript.

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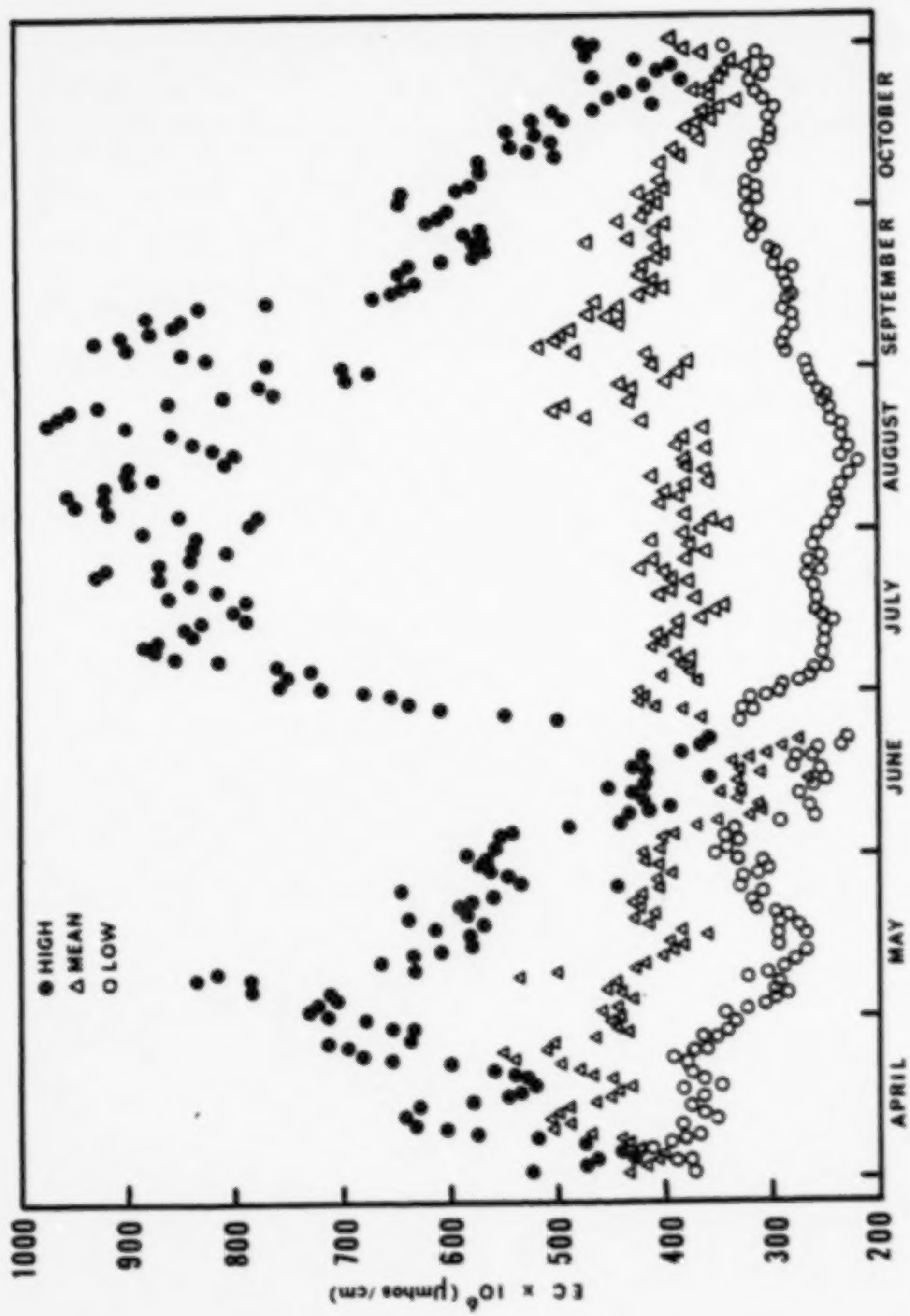
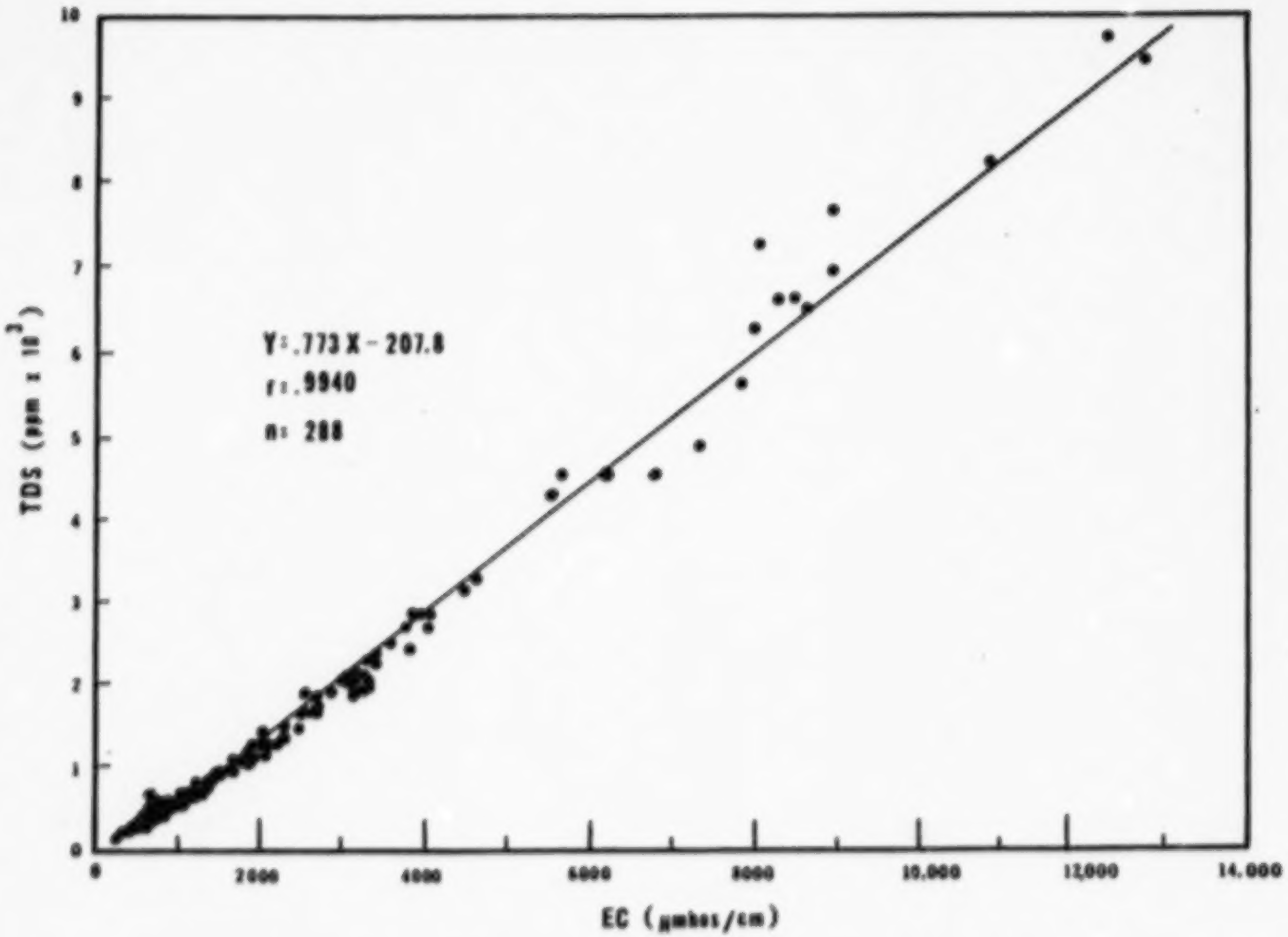
XI. APPENDICES



APP. FIG. 1: VARIATION IN EC IN THE DELTA-MENDOTA CANAL AT STATION S-2 IN 1975 FROM U.S.B.R. CONTINUOUS EC RECORDINGS.



APPENDIX FIG. 2: RELATION BETWEEN TDS AND EC FOR WATERS IN MENDOTA–CROWS LANDING RETURN FLOW GROUP, 1975.

Appendix Table 1:

Water Flows and Quality Data Supply Station S-1

Mendota-Crows Landing Return Flow Group

April 1975 Through October 1975

Date	Monthly diversion (ac-ft)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)
*4-30	21,128	622	376	28	85	0.37
6-4	26,781	462	281	45	203	
7-2	29,003	444	239	55	134	0.18
8-5	27,676	453	258	52	98	0.18
9-3	18,581	631	375	32	64	0.23
10-1	7,997	395	243	34	60	0.09

* Represents sampling for month of May.

Appendix Table 2 :

Water Flow and Quality Data Supply Station S-2
Mendota-Crows Landing Return Flow Group
April 1975 Through October 1975

Date	Monthly diversion (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)
*4-30	133,452	500	304	32	91	0.40
6-4	158,444	339	220	41	168	
7-2	169,894	280	166	55	120	0.10
8-5	161,177	952	558	42	102	0.38
9-3	102,042	272	173	38	62	0.15
10-1	68,620	326	197	30	44	0.07

* Represents sampling for Month of May.

Appendix Table 3:

Water Flow and Quality Data Discharge Station D-1
Mendota-Crows Landing Return Flow Group
April 1975 Through October 1975

Date	Discharge at sampling date (ac-ft/day)	Monthly discharge (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)
*4-30	276	7,672	1,855	1,066	37	88	1.11
6-5	127	6,018	1,752	957	17	69	0.13
7-1	290	7,587	1,097	615	44	120	0.37
8-5	276	11,470	1,200	663	52	100	0.31
8-13	210		1,305	775	33	93	0.37
8-20	645		1,088	681	43	106	0.72
8-27	530		1,248	800	48	128	0.82
9-3	405	8,299	1,217	741	46	111	0.51
9-10	308		1,146	705	39	94	0.44
9-17	188		1,522	937	23	45	0.55
9-24	206		1,342	774	28	64	0.52
10-1	329	4,976	1,023	575	44	93	0.23
10-8	206		1,504	850	20	38	0.45
10-15	119		2,118	10	21	35	0.55
10-22	87		2,471	1,428	17	22	0.70
10-29	83		2,406	1,428	12	18	0.60

* Represents sampling for month of May.

Appendix Table 4 :

Water Flow and Quality Data Discharge Station D-2

Mendota-Crows Landing Return Flow Group

April 1975 Through October 1975

Date	Discharge at sampling date (ac-ft/day)	Monthly discharge (ac-ft)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)
5-13			3,806	2,395	52	120	4.11
6-5			7,362	4,854	46	138	5.70
7-1		217	6,800	4,534	44	100	5.87
8-5	42	540	3,090	1,939	115	212	3.45
8-13	14		3,158	2,087	68	135	3.70
8-20	12		3,263	2,205	50	88	3.15
8-27	58		2,068	1,332	66	118	1.99
9-3	77	456	1,436	881	83	141	1.20
9-10	16		2,125	1,378	58	86	1.58
9-17	14		2,083	1,324	73	105	1.65
9-24	32		2,057	1,322	52	93	1.56
10-1	62	3,916	2,745	1,706	72	113	2.38
10-8	175		1,059	641	51	91	0.82
10-15	240		1,442	846	59	111	1.15
10-22	544		1,116	664	50	79	0.86
10-29	393		1,291	783	31	58	0.96

Appendix Table 5 :

Water Flow and Quality Data Discharge Station D-3

Mendota-Crows Landing Return Flow Group

April 1975 Through October 1975

Date	Discharge at sampling date (ac-ft/day)	Monthly discharge (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)
*4-30	34	1,295	662	400	170	433	0.46
6-5	20	1,396	540	332	120	446	
7-1	79	1,841	486	280	870	1,344	0.10
8-5	16	1,396	468	285	290	636	0.15
8-13	30		544	330	140	286	0.11
8-20	137		612	395	120	280	0.33
8-27	6		663	433	17	25	0.32
9-3	54	1,081	907	549	60	99	0.51
9-10	28		1,000	617	125	246	0.64
9-17	83		895	517	70	176	0.60
9-24	68		911	527	53	113	0.48
10-1	30	492	442	251	31	31	0.10
10-8	22		1,236	750	6	5	0.42
10-15	42		509	302	34	46	0.25
10-22	1		590	345	15	12	0.32
10-29	0						

* Represents sampling for month of May.

Appendix Table 6:

Water Flow and Quality Data Internal Station, I-1

Mendota-Crows Landing Return Flow Group

April 1975 Through October 1975

Date	Monthly diversion (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)
*4-30	-	785	466	50	92	0.49
6-5	-	941	555	27	73	0.32
7-1	-	936	519	45	90	0.68
8-5	-	911	482	47	73	0.44
9-3	-	940	582	22	32	0.68
10-1	-	756	437	17	17	0.15

* Represents sampling for month of May.

Appendix Table 7 :

Water Flow and Quality Data Internal Station, I-2
Mendota-Crows Landing Return Flow Group
April 1975 Through October 1975

Date	Monthly discharge (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)
*4-30	-	2,550	1,690	25	59	2.86
6-4	-	1,693	1,022	22	93	2.00
7-2	-	2,217	1,380	57	111	2.66
8-5	-	2,339	1,372	44	95	3.25
9-3	-	3,041	2,150	44	92	4.71
10-1	-	669	403	31	48	0.16

* Represents sampling for month of May.

Appendix Table 8:

Water Flow and Quality Data Internal Station, I-3
Mendota-Crows Landing Return Flow Group
April 1975 Through October 1975

Date	Monthly discharge (ac-ft)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)
*4-30	-	3,290	2,109	16	33	1.24
6-4	-	3,387	2,040	36	103	1.40
7-2	-	3,228	1,910	45	110	1.38
8-5	-	2,318	1,359	37	70	0.74
9-3	-	2,298	1,417	28	70	0.90
10-1	-	3,343	1,956	31	53	1.22

* Represents sampling for month of May.

Appendix Table 9 :

Water Flow and Quality Data Internal Station, I-5

Mendota-Crows Landing Return Flow Group

April 1975 Through October 1975

Date	Discharge at sampling date (ac-ft/day)	Monthly discharge (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)
*4-30	-	-	3,778	2,633	42	110	4.25
6-4	-	-	4,032	2,688	135	530	6.00
7-2	-	-	3,188	2,039	78	191	4.85
8-5	-	-	3,129	2,093	180	463	4.59
9-3	17	2,088	2,585	1,646	44	112	3.76
10-1	187	3,434	1,337	857	58	141	1.48

* Represents sampling for month of May.

Appendix Table 10:

Water Flow and Quality Data Internal Station, I-6

Mendota-Crows Landing Return Flow Group

April 1975 Through October 1975

Date	Discharge at sampling date (ac-ft/day)	Monthly discharge (ac-ft)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)
*4-30	101	3,939	3,290	2,306	67	202	5.36
6-4	137	4,284	3,079	1,955	110	337	4.90
7-2	111	3,941	3,036	1,999	220	615	4.80
8-5	113	3,339	2,537	1,622	145	331	3.46
9-3	87	2,100	2,721	1,823	120	323	4.45
10-1	50	1,855	4,012	2,903	87	175	6.53

* Represents sampling for month of May.

Appendix Table 11:

Water Flow and Quality Data Internal Station, I-7

Mendota-Crows Landing Return Flow Group

April 1975 Through October 1975

Date	Monthly discharge (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)
*4-30	-	911	544	74	180	0.70
6-4	-	758	468	27	96	0.26
7-2	-	975	571	59	135	0.55
8-5	-	793	472	43	61	0.43
9-3	-	802	498	53	96	0.46
10-1	-	1,304	847	60	103	1.08

* Represents sampling for month of May.

Appendix Table 12:

Water Flow and Quality Data Internal Station, I-8

Mendota-Crows Landing Return Flow Group

April 1975 Through October 1975

Date	Monthly discharge (ac-ft)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)
*5-13	1,841	1,932	1,098	8	26	0.24
6-3	2,971	806	455	51	209	
7-1	3,386	785	443	58	156	0.18
8-5	3,580	667	398	69	149	0.18
9-3	2,200	749	457	52	108	0.14
10-1	959	677	349	34	66	0.05

* Turner Island, Mariposa Slough at Mariposa Bypass.

Appendix Table 13:

Detailed Water Quality Analysis for Discharge, Supply, and Internal Stations
Mendota-Crows Landing Return Flow Group*
1975 Irrigation Season

Date	EC (µmhos/cm)	Na	Ca	Mg	HCO_3	Cl	SO_4	Total N	Organic N	NH_4-N	NO_3-N	NO_2-N	BOD
		meq/ℓ						mg/ℓ					
Discharge Station D-1													
6-5	1,752	9.50	4.50	2.90	3.34	9.35	4.10	--	--	--	--	--	--
8-5	1,200	5.88	2.50	2.50	2.97	5.41	2.60	--	--	--	--	--	--
9-3	1,217	5.88	3.50	2.75	3.34	5.55	3.00	1.69	1.05	0.05	0.560	0.033	0.6
Discharge Station D-2													
6-5+	7,362	56.00	9.50	14.50	5.22	36.53	39.00	--	--	--	--	--	--
8-5	3,090	20.25	5.75	6.50	4.28	14.85	14.50	--	--	--	--	--	--
9-3	1,436	7.50	3.75	4.00	4.38	5.27	5.35	2.29	1.92	0.08	0.264	0.021	7.2
+Mud Slough north at Highway 140.													
Discharge Station D-3													
6-5	540	2.05	1.65	1.25	1.83	1.57	1.50	--	--	--	--	--	--
8-5	468	1.55	1.50	1.25	1.93	1.05	1.78	--	--	--	--	--	--
9-3	907	3.80	2.90	2.90	3.55	2.90	2.80	3.43	0.87	8.03	2.500	0.030	0.6
Supply Station S-1													
6-4	462	2.00	1.30	1.05	1.41	1.66	0.88	--	--	--	--	--	--
8-5	453	1.85	1.20	1.15	1.51	1.61	1.04	--	--	--	--	--	--
9-3	631	3.00	1.90	1.60	2.30	2.62	1.25	1.67	0.66	0.04	0.960	0.006	0.6

*Flow, TDS, turbidity, SS, and B are given in Appendix Tables 1-12 for the corresponding stations.

Appendix Table 13: (continued)

Date	EC (µmhos/cm)	Na	Ca	Mg	HCO_3	Cl	SO_4	Total N	Organic N	NH_4-N	NO_3-N	NO_2-N	BOD
		meq/l						mg/l					
Supply Station S-2													
6-4	339	1.38	1.03	0.83	1.31	1.12	0.83	--	--	--	--	--	--
8-5	952	4.50	2.60	2.00	2.76	4.54	2.30	--	--	--	--	--	--
9-3	272	1.13	0.83	0.88	1.41	0.70	0.54	1.06	0.30	0.12	0.560	0.001	0.6
Internal Station I-1													
6-5	941	4.20	2.80	2.30	3.13	2.84	3.20	--	--	--	--	--	--
8-5	911	3.60	2.70	2.10	3.18	2.85	2.70	--	--	--	--	--	--
9-3	940	4.20	3.00	2.70	3.24	3.07	3.10	2.71	0.43	0.07	2.190	0.017	0.6
Internal Station I-2													
6-4	1,693	8.75	5.00	2.70	2.71	6.16	7.50	--	--	--	--	--	--
8-5	2,339	14.38	3.50	3.75	3.39	8.93	10.00	--	--	--	--	--	--
9-3	3,041	16.50	10.00	6.50	3.76	10.82	18.00	1.71	1.18	0.52	0.012	0.000	3.6
Internal Station I-3													
6-4	3,387	18.40	9.00	7.40	3.55	17.49	13.50	--	--	--	--	--	--
8-5	2,318	12.25	5.25	5.00	2.76	11.41	7.80	--	--	--	--	--	--
9-3	2,298	11.75	5.00	6.50	3.34	12.14	8.02	2.64	1.35	0.05	1.000	0.240	2.4
Internal Station I-5													
6-4	4,032	23.00	14.75	5.80	3.34	16.25	23.50	--	--	--	--	--	--
8-5	3,129	16.62	10.25	5.62	3.60	11.86	17.50	--	--	--	--	--	--
9-3	2,585	15.25	8.00	4.00	4.18	9.55	14.00	5.22	0.69	0.21	4.300	0.016	0.6

Appendix Table 13: (continued)

Date	EC (µmhos/cm)	Na	Ca	Mg	HCO_3	Cl	SO_4	Total N	Organic N	NH_4-N	NO_3-N	NO_2-N	BOD
		meq/ℓ						mg/ℓ					
Internal Station I-6													
6-4	3,079	18.40	9.40	2.20	2.92	11.85	15.50	--	--	--	--	--	--
8-5	2,537	13.88	7.25	4.00	2.97	9.38	12.50	--	--	--	--	--	--
9-3	2,721	13.55	9.00	5.50	3.76	10.34	13.50	13.45	0.70	0.10	12.600	0.048	0.6
Internal Station I-7													
6-4	758	3.60	2.50	1.50	2.51	2.16	2.60	--	--	--	--	--	--
8-5	793	3.50	2.70	1.50	2.45	2.06	2.90	--	--	--	--	--	--
9-3	802	3.90	2.50	1.60	2.92	2.34	3.20	0.64	0.30	0.20	0.136	0.007	0.6
Internal Station I-8													
6-4	806	3.40	2.50	1.60	2.40	3.10	1.75	--	--	--	--	--	--
8-5	667	3.00	2.10	1.30	2.35	2.46	1.68	--	--	--	--	--	--
9-3	749	3.10	2.40	1.80	2.09	3.18	1.50	1.39	0.34	0.06	0.920	0.067	0.6

Appendix Table 14:

Locations of Water Sampling Stations in Broadview Water District

Mendota-Crows Landing Return Flow Group

1975

No.	Sampling ID	Sampling location (Township, range and section)	Sample Description
1	BWD-1	13S13E16	Water sample from drain along Hudson Avenue in corner of Ashlan Avenue. Gravity inflow to Broadview Water District from Westlands Water District.
2	BWD-2	13S14E9	Water sample from the drain along Firebaugh Canal east of Lyon and south of Shaw Avenue. Inflow to Broadview Water District from Westlands Water District.
3	BWD-3	12S13E33	Water sample from the lower end of the drain at pumps in corner of Nees Avenue and Fairfax Avenue.
4	BWD-4	12S13E33	Water sample from the supply canal along Fairfax Avenue below the drain discharge from pumps, i.e., mixture of DMC and drain water.
5	BWD-5	12S13E21	Water sample from Delta Mendota Canal at Fairfax Avenue.

Appendix Table 15:

Water Flow and Quality Data, Broadview Water District
Mendota-Crows Landing Return Flow Group
April 1975 through October 1975

Date	Monthly flow (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)
BWD-1						
5-1	—	580	336	98	220	0.42
6-4	—	706	386	325	983	0.13
7-2	189	708	378	81	160	0.32
8-5	164	718	393	12	7	0.38
9-3	5	481	298	65	91	0.28
10-1	--	--	--	—	—	--
BWD-2						
5-1	—	3,000	2,088	225	561	1.76
6-4	--	941	506	35	370	0.20
7-2	1,342	1,522	951	42	75	0.94
8-5	695	1,010	569	145	298	0.46
9-3	--	923	576	130	325	0.59
10-1	--	501	321	36	43	0.17
BWD-3						
5-1	1,539	4,435	3,157	89	260	3.55
6-4	3,043	2,117	1,253	225	773	1.22
7-2	2,566	2,040	1,310	94	207	1.40
8-5	1,357	1,923	1,297	150	362	1.57
9-3	410	1,846	1,271	363	993	1.54
10-1	630	3,259	2,254	70	164	3.18

Appendix Table 15 (continued)

Date	Monthly flow (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)
BWD-4						
5-1	2,804	3,400	2,332	69	166	2.31
6-4	5,924	1,037	606	80	367	0.32
7-2	5,176	1,546	915	82	196	0.95
8-5	2,489	1,067	644	94	222	0.51
9-3	755	708	618	98	182	0.60
10-1	1,660	1,410	906	38	73	1.12
BWD-5						
5-13	1,265	555	302	32	91	0.33
6-4	2,881	446	268	24	183	0.00
7-2	2,670	729	409	52	139	0.25
8-5	1,132	600	332	63	120	0.20
9-3	345	259	168	31	45	0.10
10-1	1,030	411	243	22	33	0.13

Appendix Table 16:

Detailed Water Quality Analysis for Broadview Water District

Mendota-Crows Landing Return Flow Group*

1975 Irrigation Season

Date	EC (µmhos/cm)	Na	Ca	Mg	HCO_3	Cl	SO_4	Total N	Organic N	NH_4-N	NO_3-N	NO_2-N	BOD
		meq/ℓ						mg/ℓ					
BWD-1													
6-4	706	4.20	1.85	1.00	2.51	2.35	1.63	--	--	--	--	--	--
8-5	718	3.45	2.10	1.30	3.08	2.34	1.15	--	--	--	--	--	--
9-3	481	2.75	1.65	0.90	2.51	1.24	1.28	1.18	0.75	0.05	0.336	0.046	0.6
BWD-2													
6-4	941	4.00	2.80	1.70	2.30	2.98	2.60	--	--	--	--	--	--
8-5	1,010	4.60	3.00	1.50	4.38	3.08	3.30	--	--	--	--	--	--
9-3	923	4.50	3.20	1.80	2.30	2.88	4.20	3.87	1.41	0.09	2.250	0.116	2.4
BWD-3													
6-4	2,117	11.00	6.38	2.70	2.09	6.96	10.25	--	--	--	--	--	--
8-5	1,943	10.50	5.75	2.25	2.19	6.54	10.58	--	--	--	--	--	--
9-3	1,846	10.50	5.50	3.25	2.71	6.20	10.25	10.20	2.01	0.09	8.000	0.098	2.4

*Flow, TDS, turbidity, SS and B are given in Appendix Table 15 for the corresponding station.

Appendix Table 16 (continued)

Date	EC (μmhos/cm)	Na	Ca	Mg	HCO_3	Cl	SO_4	Total N	Organic N	NH_4-N	NO_3-N	NO_2-N	BOD
BWD-4		meq/ℓ						mg/ℓ					
6-4	1,037	5.10	3.30	0.90	1.57	3.27	4.30	--	--	--	--	--	--
8-5	1,067	5.07	2.62	1.75	2.45	4.15	3.90	--	--	--	--	--	--
9-3	708	4.80	3.00	2.05	1.98	3.16	4.20	4.35	0.97	0.03	3.300	0.046	0.6
BWD-5													
6-4	446	2.20	1.45	1.05	1.36	1.75	1.13	--	--	--	--	--	--
8-5	600	--	--	--	--	--	--	--	--	--	--	--	--
9-3	259	1.15	0.88	0.83	1.31	0.79	0.51	1.14	0.45	0.05	0.640	0.002	4.2

Appendix Table 17: Location of Soil Sampling Sites in

Broadview Water District, 1975

No.	Sampling Date	Sample I.D.	Sampling Location (township, range and section)	Sampling Depth, ft.	Crop
1	8-28	BWD-S14	12S13E33	9	Barley
2	8-28	BWD-S15	13S13E4	8	Alfalfa
3	8-29	BWD-S16	13S13E3	8	Cotton
4	8-29	BWD-S17	13S13E9	5	Tomato
5	8-29	BWD-S18	13S13E16	13	Tomato
6	8-29	BWD-S19	13S13E10	10	Cotton
7	8-29	BWD-S20	13S13E15	11	Tomato

Appendix Table 18:

Soil Analyses in Broadview Water District

1975

Location	Depth (ft.)	Sat. %	EC_e (mmhos/cm)	Cl (meq/ℓ)	SO_4 (meq/ℓ)	B (mg/ℓ)	Estimated soluble salts (tons/ac-ft)	Gypsum (tons/ac-ft)
BWD S14	0-½	57	7.67	28.5	54.0	2.85	5.57	9.79
	½-1	77	7.13	14.7	63.0	2.72	7.00	43.29
	1-1½	67	7.33	15.9	68.0	2.66	6.26	99.00
	1½-2	73	6.21	10.1	57.0	1.70	5.83	1.41
	2-3	67	4.12	6.2	42.0	1.90	3.52	0.34
	3-4	70	5.80	3.8	73.0	1.98	5.20	7.98
	4-5	70	5.99	4.5	82.0	2.60	5.37	50.33
	5-6	70	6.13	5.1	63.7	2.66	5.49	22.43
	6-7	70	6.13	4.8	74.5	2.30	5.49	19.40
	7-8	73	5.73	3.6	63.7	2.20	5.38	16.91
	8-9	73	5.86	4.2	73.0	2.10	5.50	15.74
BWD S15	0-½	77	8.41	36.6	48.0	2.45	8.26	1.07
	½-1	80	4.92	20.8	24.0	2.25	5.04	0.83
	1-1½	83	4.35	19.7	19.5	1.90	4.64	1.34
	1½-2	88	3.95	13.4	22.0	2.10	4.46	0.79
	2-3	83	5.79	12.3	48.8	2.10	6.17	0.07
	3-4	95	6.06	8.7	61.0	2.00	7.37	67.49
	4-5	53	6.14	10.3	61.0	2.10	4.19	26.23
	5-6	58	4.74	7.0	55.0	1.58	3.54	17.70
	6-7	57	4.28	7.4	52.0	1.20	3.11	12.81
	7-8	65	3.48	4.3	42.0	1.00	2.90	19.38
BWD S16	0-½	40	4.97	20.2	13.0	0.52	2.54	0.58
	½-1	38	1.80	6.7	5.0	0.33	0.88	0.38
	1-1½	37	1.21	4.2	3.2	0.30	0.57	0.40
	1½-2	40	1.19	4.9	2.5	0.32	0.61	0.24
	2-3	37	0.64	1.8	2.1	0.20	0.30	0.21
	3-4	33	1.06	3.0	4.5	0.26	0.45	0.17
	4-5	33	1.77	8.5	7.5	0.40	0.75	0.36
	5-6	42	2.93	14.2	16.0	0.52	1.56	0.36
	6-7	47	2.05	7.3	13.0	0.70	1.23	0.38
	7-8	50	2.06	7.6	10.5	0.60	1.32	0.38
BWD S17	0-½	70	15.80	105.1	49.2	2.60	14.16	3.03
	½-1	77	8.41	38.0	46.3	1.82	8.26	1.46
	1-1½	83	4.14	23.2	14.0	1.30	4.41	1.12
	1½-2	90	3.73	18.9	12.0	1.15	4.30	0.98
	2-3	90	3.37	17.4	10.5	1.20	3.88	0.69
	3-4	88	2.29	11.2	7.0	1.35	2.59	0.53
	4-5	[illegible]	[illegible]	7.7	5.5	[illegible]	1.76	[illegible]

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Appendix Table 18: Continued

Location	Depth (ft.)	Sat. %	EC_e (mmhos/cm)	Cl (meq/ℓ)	SO_4 (meq/ℓ)	B (mg/ℓ)	Estimated soluble salts (tons/ac-ft)	Gypsum (tons/ac-ft)
BWD S18	0-½	40	4.40	13.3	12.5	1.25	2.25	0.57
	½-1	41	2.32	6.6	5.4	0.50	1.22	0.50
	1-1½	41	1.89	5.7	4.4	0.50	0.99	0.40
	1½-2	43	1.31	4.0	3.9	0.42	0.71	0.41
	2-3	39	1.13	3.6	4.2	0.50	0.56	0.48
	3-4	40	1.28	3.7	5.1	0.70	0.66	0.58
	4-5	34	1.31	3.3	6.3	0.90	0.57	0.29
	5-6	33	1.21	2.5	6.0	1.00	0.50	0.17
	6-7	59	6.89	18.8	66.0	4.50	5.16	0.07
	7-8	28	0.98	2.2	4.4	0.82	0.35	0.24
	8-9	37	1.06	2.5	4.8	0.86	0.50	0.19
	10-11	64	1.16	3.2	5.6	0.70	0.94	0.46
	11-12	46	1.24	3.2	5.8	0.88	0.73	0.41
	12-13	46	1.31	3.4	6.8	0.95	0.77	0.34
BWD S19	0-½	42	8.87	22.5	46.0	2.10	4.73	5.30
	½-1	50	3.07	7.3	10.5	0.40	1.96	0.60
	1-1½	43	3.12	7.6	10.5	0.26	1.73	0.36
	1½-2	47	2.32	4.6	10.0	0.32	1.39	0.53
	2-3	53	1.47	2.5	6.0	0.48	1.00	0.62
	3-4	50	1.29	3.0	5.3	0.48	0.83	0.50
	4-5	38	1.47	4.3	7.5	0.42	0.72	0.26
	5-6	53	1.63	4.2	8.8	0.26	1.11	0.28
	6-7	43	1.35	3.5	7.5	0.68	0.75	0.29
	7-8	60	1.13	2.7	6.0	0.52	0.87	1.44
	8-9	50	1.34	3.5	7.0	0.68	0.86	0.34
	9-10	50	2.45	6.3	12.5	0.48	1.57	0.69
BWD S20	0-½	60	2.27	7.0	11.1	1.10	1.74	0.43
	½-1	60	1.24	3.3	6.3	1.00	0.95	0.55
	1-1½	63	1.56	5.2	8.2	0.86	1.26	0.71
	1½-2	60	3.07	13.4	18.8	1.00	2.36	0.74
	2-3	55	4.35	18.9	30.0	1.45	3.06	0.46
	3-4	53	4.50	20.1	30.0	1.70	3.07	0.48
	4-5	62	4.42	17.9	30.0	1.70	3.49	1.29
	5-6	68	4.58	17.2	31.5	1.85	4.00	1.12
	6-7	63	5.43	18.7	43.5	1.85	4.40	0.26
	7-8	65	4.83	14.2	39.0	1.65	4.02	0.10
	8-9	77	3.48	9.1	28.0	1.22	3.42	1.12
	9-10	80	3.16	7.0	25.5	1.15	3.24	0.43
	10-11	65	3.16	7.6	25.0	1.22	2.63	0.21

Appendix Table 19:

Locations of Water Sampling Stations in Panoche Water District

Mendota-Crows Landing Return Flow Group

1975

No.	Sampling ID	Sampling location (Township, range and section)	Sample Description
1	PWD-1	12S11E11	Delta Mendota Canal water sample from Lift #1 at Orleans.
2	PWD-2	12S11E23	Water sample from the canal at Lift #4 along Orleans.
3	PWD-3	13S11E2	California Aqueduct water sample from turnout #1 at Orleans.
4	PWD-4T	12S12E32	Tomato field, southwest corner inlet. Water sample along Herndon.
5	PWD-5T	12S12E32	Tomato field, southeast corner. Mixture of Canal and recycled water, along Herndon.
6	PWD-6T	12S12E32	Tomato field, southeast corner. Water sample from the Canal at Herndon.
7	PWD-7T	12S12E32	Tomato field, southeast corner, water sample from recycling water sump, along Herndon.
8	PWD-8E	12S12E27	Tile drained farm, overall supply. Water sample along Russell Avenue.
9	PWD-9E	12S12E27	Tile drained farm, supply water from the District ditch between Nees and Shepard along Russell Avenue.
10	PWD-10E	12S12E27	Tile drained farm, drain water sample before mixing with District supply along Russell Avenue.
11	PWD-11E	12S12E26	Tile drained farm, water sample from the tile sump in northwest corner of Section 26.
12	PWD-12E	12S12E25	Tile drained farm, water sample from the tile sump in northwest corner of Section 25.
13	PWD-13E	12S12E27	Hammond drain water sample from southeast corner of Section 27 along Nees Avenue.
14*	PWD-14	12S11E11	Drain water sample at the lift pump from corner of Outside Canal and Orleans Avenue.
15*	PWD-15	12S12E17	Drain water sample at the lift pump from corner of Courtney Avenue and Prince Avenue.

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*These Stations were added to the

Appendix Table 20:

Water Flow and Quality Data, Panoche Water District

Mendota-Crows Landing Return Flow Group

April 1975 through October 1975

Date	Monthly flow (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)
PWD-1						
5-13	7,939	586	335	41	113	0.41
6-4	11,153	343	212	20	129	0
7-2	11,303	258	158	49	96	0.10
8-5	8,054	249	148	51	95	0.04
9-3	2,106	483	287	29	50	0.18
10-1	3,462	404	237	23	32	0.12
PWD-2						
5-13	3,922	478	280	58	203	0.40
6-4	7,005	550	312	28	130	0
7-2	6,393	810	448	45	133	0.32
8-5	4,883	378	224	53	82	0.19
9-3	758	795	484	15	16	0.93
10-1	1,933	567	339	16	11	0.37
PWD-3						
5-13	2,741	579	325	13	25	0.40
6-4	4,493	463	261	4	13	0
7-2	7,658	472	251	3	9	0.16
8-5	6,052	357	202	18	17	0.09
9-3	1,799	265	166	68	87	0.32
10-1	353	274	169	8	1	0.09

Appendix Table 21:

Detailed Water Quality Analysis for Panoche Water District

Mendota-Crows Landing Return Flow Group*

1975 Irrigation Season

Date	EC (µmhos/cm)	Na	Ca	Mg	HCO_3	Cl	SO_4	Total N	Organic N	NH_4-N	NO_3-N	NO_2-N	BOD
		meq/ℓ						mg/ℓ					
PWD-1													
6-4	343	1.45	1.10	0.75	1.25	1.24	0.75	—	—	—	—	—	—
9-3	483	2.25	1.40	1.25	1.78	1.92	1.02	1.69	0.64	0.06	0.98	0.007	0.6
PWD-2													
6-4	550	2.40	1.60	0.90	1.31	1.62	1.45	—	—	—	—	—	—
9-3	795	3.70	2.80	1.80	1.57	3.38	2.40	4.72	0.24	0.06	4.40	0.015	0.6
PWD-3													
6-4	463	2.05	1.50	1.05	1.77	1.63	0.74	—	—	—	—	—	—
9-3	265	1.23	0.90	0.82	1.46	0.85	0.48	0.57	0.27	0.03	0.26	0.007	0.6

*Flow, TDS, turbidity, SS and B are given in Appendix Table 20 for corresponding station.

Appendix Table 21: Continued

Detailed Water Quality Analysis for Tile Drained Farm, Panoche Water District
Mendota-Crows Landing Return Flow Group*
1975 Irrigation Season

Date	EC (µmhos/cm)	Na	Ca	Mg	HCO_3	Cl	SO_4	Total N	Organic N	NH_4-N	NO_3-N	NO_2-N	BOD
		meq/ℓ						mg/ℓ					
PWD-8E													
6-4	1,282	6.78	4.50	1.50	1.67	4.02	6.20	--	--	--	--	--	--
PWD-9E													
6-4	352	1.65	1.10	0.75	1.25	1.32	0.70	--	--	--	--	--	--
PWD-10E													
6-4	1,724	8.75	5.25	2.70	1.78	5.15	9.25	--	--	--	--	--	--
PWD-11E													
6-4	10,870	78.50	31.50	16.00	5.74	46.39	75.50	--	--	--	--	--	--
9-3	10,616	79.50	31.00	20.50	4.70	51.25	70.00	84.630	0.58	0.02	84.00	0.023	0.6
PWD-12E													
6-4	8,621	56.00	31.00	16.00	5.74	37.66	61.00	--	--	--	--	--	--
9-3	8,078	63.00	33.00	21.50	4.86	47.03	64.50	24.616	0.51	0.09	24.00	0.016	0.6
PWD-13E													
6-4	1,471	7.50	5.25	1.80	1.98	4.36	7.50	--	--	--	--	--	--
9-3	1,456	7.25	5.25	2.75	2.09	4.46	7.92	10.827	2.16	0.04	8.60	0.027	0.6

*Flow, TDS, turbidity, SS and B are given in Appendix Table 24 for the corresponding station.

Appendix Table 22: Location of Soil Sampling Sites in

Panoche Water District, 1975

No.	Sampling Date	Sample I.D.	Sampling Location (township, range and section)	Sampling Depth, ft.	Crop
1	8-26	PWD-S1	12S12E7	10	Wheat
2	8-26	PWD-S2	12S12E23	7	Tomato
3	8-26	PWD-S3	12S12E32	12	Tomato
4	8-27	PWD-S4	12S12E29	8	Tomato
5	8-27	PWD-S5	12S12E29	7	Tomato
6	8-27	PWD-S6	12S12E27	12	Tomato
7	8-27	PWD-S7	12S12E27	7	Wheat
8	8-27	PWD-S8	12S12E27,26	11	Cotton
9	8-28	PWD-S9	12S12E26	8	Wheat
10	8-28	PWD-S10	12S12E26	6	Wheat
11	8-28	PWD-S11	12S12E25	8	Tomato
12	8-28	PWD-S12	12S12E34	9	Garlic
13	8-28	PWD-S13	13S12E9	8	Tomato

Appendix Table 23:

Soil Analyses in Panoche Water District

1975

Location	Depth (ft.)	Sat. %	EC_e (mmhos/cm)	Cl (meq/ℓ)	SO_4 (meq/ℓ)	B (mg/ℓ)	Estimated soluble salts (tons/ac-ft)	Gypsum (tons/ac-ft)
PWD S1	0-½	45	2.17	7.7	10.3	2.00	1.25	0.41
	½-1	52	3.67	13.3	15.3	1.58	2.42	0.50
	1-1½	53	3.16	10.6	13.5	1.65	2.13	0.41
	1½-2	54	1.30	3.9	4.3	0.90	0.91	0.21
	2-3	49	1.11	2.6	4.3	0.90	0.69	0.24
	3-4	71	1.19	2.9	4.1	1.40	1.07	0.34
	4-5	55	1.21	3.2	5.0	1.50	0.85	0.22
	5-6	40	1.16	3.0	4.6	1.80	0.59	0.26
	6-7	38	1.06	2.5	4.3	1.80	0.52	0.38
	8-9	45	1.41	4.1	6.0	2.05	0.81	0.41
	9-10	45	1.02	2.7	3.9	1.90	0.59	0.40
PWD S2	0-½	54	0.82	1.5	2.8	1.10	0.57	0.05
	½-1	53	0.83	1.4	3.1	1.18	0.56	0.17
	1-1½	54	0.77	1.4	2.8	1.30	0.53	0.05
	1½-2	50	0.80	1.4	4.0	1.50	0.51	0.31
	2-3	30	0.87	1.7	4.0	1.50	0.33	0.24
	3-4	43	1.21	4.2	4.6	1.75	0.67	0.34
	4-5	47	3.73	21.0	12.5	4.60	2.23	0.48
	5-6	48	4.83	24.7	19.0	4.60	2.99	0.48
	6-7	43	4.31	22.1	19.5	3.48	2.39	0.48
PWD S3	0-½	45	0.71	1.5	2.1	0.64	0.41	0.07
	½-1	43	0.56	0.9	1.4	0.60	0.31	0.07
	1-1½	40	0.61	1.1	2.0	0.40	0.31	0.17
	1½-2	39	0.57	0.9	1.7	0.40	0.28	0.15
	2-3	37	0.55	1.0	1.7	0.50	0.26	0.33
	3-4	37	0.58	1.0	1.8	0.64	0.27	0.29
	4-5	37	0.53	1.0	1.7	0.70	0.25	0.33
	5-6	38	0.57	1.1	1.9	0.75	0.28	1.00
	6-7	33	0.53	1.1	1.8	0.64	0.23	0.14
	7-8	27	0.55	1.2	1.9	0.80	0.19	0.22
	8-9	30	0.67	1.3	2.2	0.90	0.26	0.21
	9-10	33	0.88	2.4	2.6	1.30	0.38	0.24
	10-11	30	0.82	1.9	2.4	1.25	0.32	0.22
	11-12	32	0.83	1.9	2.1	1.10	0.34	0.14

Appendix Table 23 : Continued

Location	Depth (ft.)	Sat. %	EC_e (mmhos/cm)	Cl (meq/ℓ)	SO_4 (meq/ℓ)	B (mg/ℓ)	Estimated soluble salts (tons/ac-ft)	Gypsum (tons/ac-ft)
PWD S4	0-½	47	1.80	4.3	5.3	0.32	1.08	0.45
	½-1	53	0.76	2.2	2.6	0.36	0.52	0.45
	1-1½	63	1.47	5.6	7.0	1.60	1.19	0.33
	1½-2	57	2.82	8.4	18.5	3.50	2.05	0.53
	2-3	60	4.17	14.3	29.5	4.60	3.20	0.72
	3-4	60	5.11	21.9	28.0	5.02	3.92	0.07
	4-5	60	5.06	17.3	42.0	4.25	3.89	0.83
	5-6	50	3.86	19.0	20.5	3.72	2.47	0.29
	6-7	62	2.98	12.8	16.3	3.00	2.35	0.55
	7-8	65	1.77	5.9	9.9	2.32	1.47	0.41
PWD S5	0-½	48	1.80	4.8	6.0	1.05	1.11	0.45
	½-1	52	1.71	6.4	6.5	1.15	1.13	0.53
	1-1½	52	2.09	9.7	9.1	1.55	1.38	0.48
	1½-2	50	4.21	22.9	18.3	2.40	2.69	1.05
	2-3	53	5.79	25.4	21.0	5.92	3.95	2.17
	3-4	53	6.86	29.9	45.0	7.55	4.68	1.38
	4-5	50	5.67	28.9	31.5	5.50	3.63	0.29
	5-6	58	4.21	22.3	22.0	4.43	3.14	0.29
	6-7	58	3.48	17.7	16.0	3.45	2.60	0.46
PWD S6	0-½	60	2.71	6.9	20.0	2.20	2.08	0.91
	½-1	60	2.57	7.5	16.0	2.10	1.97	0.58
	1-1½	68	2.10	5.5	11.0	1.70	1.84	0.77
	1½-2	70	2.19	5.8	13.0	1.50	1.96	0.77
	2-3	67	2.14	5.4	15.8	1.15	1.83	0.74
	3-4	67	2.71	4.9	21.0	1.30	2.31	0.41
	4-5	72	2.24	4.9	16.3	1.15	2.06	2.48
	5-6	73	2.06	4.8	13.0	1.10	1.93	0.98
	6-7	70	1.91	4.9	11.0	1.00	1.71	0.60
	7-8	70	1.94	5.4	11.0	1.10	1.74	0.40
	8-9	70	1.98	5.4	11.0	0.93	1.77	0.60
	9-10	63	2.24	7.8	11.0	1.40	1.81	1.62
	10-11	60	2.78	10.6	17.0	2.04	2.14	0.48
	11-12	60	4.12	14.7	29.0	5.40	3.16	0.58

Appendix Table 23 : Continued

Location	Depth (ft.)	Sat. %	EC_e (mmhos/cm)	Cl (meq/ℓ)	SO_4 (meq/ℓ)	B (mg/ℓ)	Estimated soluble salts (tons/ac-ft)	Gypsum (tons/ac-ft)
PWD S7	0-½	63	2.57	9.7	9.8	2.80	2.08	0.72
	½-1	63	2.85	10.4	10.8	3.50	2.31	0.83
	1-1½	60	1.73	4.8	9.9	1.98	1.33	0.57
	1½-2	70	4.00	8.3	33.0	1.98	3.58	0.84
	2-3	83	8.79	18.3	82.3	4.90	9.37	14.02
	3-4	73	8.94	17.7	79.0	4.95	8.39	43.17
	4-5	77	7.99	15.1	81.0	4.72	7.84	32.32
	5-6	70	8.51	13.5	84.3	5.42	7.62	22.53
	6-7	60	7.87	9.1	82.3	5.20	6.04	18.16
PWD S8	0-½	77	8.94	43.0	46.8	3.08	8.78	8.02
	½-1	77	8.24	33.8	50.3	3.30	8.09	9.51
	1-1½	73	7.43	28.9	50.0	2.40	6.97	2.98
	1½-2	80	4.63	22.1	19.3	1.90	4.74	1.48
	2-3	83	4.88	20.3	30.1	2.30	5.20	1.19
	3-4	77	4.71	17.6	29.5	2.30	4.62	0.93
	4-5	73	4.59	14.4	33.5	2.40	4.31	1.27
	5-6	67	6.13	13.7	56.3	3.20	5.23	12.47
	6-7	70	6.68	14.5	64.0	4.65	5.99	18.95
	7-8	80	6.85	13.9	67.0	5.00	7.01	22.60
	8-9	83	6.90	11.9	68.0	5.80	7.36	16.92
	9-10	103	7.23	9.5	75.5	6.50	9.56	13.28
	10-11	100	7.99	11.1	84.3	7.20	10.23	23.75
PWD S9	0-½	85	2.08	4.5	10.9	3.35	2.26	0.83
	½-1	68	3.76	6.3	28.0	3.70	3.25	2.77
	1-1½	100	6.11	10.5	58.0	3.75	7.82	1.38
	1½-2	103	8.80	15.2	90.0	4.95	11.55	5.62
	2-3	100	11.53	23.5	112.5	7.92	14.76	48.40
	3-4	93	13.31	41.0	115.0	11.40	15.76	58.58
	4-5	105	13.66	47.6	112.5	12.48	18.36	55.26
	5-6	125	14.83	63.2	136.8	14.48	23.76	26.64
	6-7	123	15.73	72.8	106.0	15.60	24.66	17.22
	7-8	85	18.87	107.4	105.0	20.30	20.53	32.80

Appendix Table 23 : Continued

Location	Depth (ft.)	Sat. %	EC_e (mmhos/cm)	Cl (meq/ℓ)	SO_4 (meq/ℓ)	B (mg/ℓ)	Estimated soluble salts (tons/ac-ft)	Gypsum (tons/ac-ft)
PWD S10	0-½	68	2.97	7.7	14.0	3.90	2.57	1.00
	½-1	83	3.24	8.7	21.3	2.65	3.42	1.74
	1-1½	83	5.30	17.4	37.0	3.50	5.60	0.26
	1½-2	80	7.01	20.3	57.0	4.25	7.18	0.07
	2-3	83	8.65	19.1	82.3	4.30	9.13	16.70
	3-4	80	8.11	17.3	76.0	3.35	8.30	23.08
	4-5	53	8.11	27.8	70.5	3.10	5.45	38.36
	5-6	55	7.86	26.8	75.3	4.25	5.53	10.51
PWD S11	0-½	78	2.04	4.3	13.6	1.55	2.02	0.88
	½-1	78	1.86	3.5	11.5	1.72	1.85	0.62
	1-1½	75	2.00	4.6	11.3	1.85	1.92	0.48
	1½-2	70	1.86	4.0	10.6	2.10	1.67	0.50
	2-3	85	2.13	4.0	14.1	1.95	2.32	0.17
	3-4	85	2.55	4.9	17.7	2.30	2.77	0.09
	4-5	90	5.20	3.7	59.3	2.40	5.99	0.10
	5-6	93	5.10	4.1	58.0	2.55	6.04	0.40
	6-7	90	5.54	5.3	61.3	2.70	6.38	0.83
	7-8	83	5.80	7.3	70.0	3.00	6.12	1.41
PWD S12	0-½	68	2.36	1.8	6.0	0.86	2.04	0.46
	½-1	68	1.40	1.6	5.9	1.75	1.21	0.40
	1-1½	80	1.89	1.7	6.8	1.85	1.94	0.53
	1½-2	90	2.00	1.5	6.7	1.90	2.30	0.69
	2-3	85	3.71	1.6	28.0	2.05	4.04	0.21
	3-4	73	5.77	1.6	70.3	3.40	5.35	19.63
	4-5	78	6.36	1.6	76.0	3.68	6.37	12.99
	5-6	80	6.60	2.2	76.0	4.83	6.76	21.36
	6-7	78	6.21	4.1	75.0	5.53	6.22	25.16
	7-8	83	5.99	5.6	71.0	5.59	6.39	37.99
	8-9	82	5.86	5.0	69.0	5.60	6.13	28.14
PWD S13	0-½	55	0.63	1.0	2.2	0.60	0.44	0.45
	½-1	55	0.70	1.1	2.1	0.65	0.49	0.19
	1-1½	65	0.97	1.9	4.4	2.10	0.81	0.76
	1½-2	40	1.17	2.4	5.7	2.10	0.60	0.40
	2-3	38	1.15	2.8	5.0	1.84	0.56	0.33
	3-4	50	1.51	4.1	7.0	2.06	0.97	0.81
	4-5	67	1.74	3.9	10.1	1.90	1.49	0.76
	5-6	70	4.35	3.2	52.0	1.62	3.90	7.84
	6-7	77	4.62	4.6	57.0	1.70	4.54	2.80
	7-8	80	4.35	4.9	64.0	1.90	4.45	21.29

Appendix Table 24:

Water Flow and Quality Data for Tile Drained Farm
Panoche Water District, Mendota-Crows Landing Return Flow Group
April 1975 through October 1975

Date	Monthly flow (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)
PWD-8E						
5-13	--	3,068	2,021	27	53	4.00
6-4	1,249	1,282	779	42	61	0.95
7-2	990	1,555	966	32	53	1.70
8-5	229	1,220	846	43	59	1.50
9-3	4	--	--	--	--	--
10-1	1,284	--	--	--	--	--
PWD-9E						
5-13	225	446	241	8	15	0.21
6-4	546	352	214	29	87	0
7-2	315	285	173	27	29	0.24
8-5	35	231	141	23	20	0.02
9-3	4	--	--	--	--	--
10-1	1,219	--	--	--	--	--
PWD-10E						
5-13	200*	3,259	2,313	31	65	4.85
6-4	703	1,724	1,096	82	227	1.90
7-2	675	2,297	1,477	40	65	2.91
8-5	194	1,667	1,136	45	75	2.13
9-3	0	--	--	--	--	--
10-1	65	--	--	--	--	--

*Flow for one week only.

Appendix Table 24 (continued)

Date	Monthly flow (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)
PWD-11E						
5-13	6*	8,991	7,639	3	13	20.55
6-4	15	10,870	8,220	1	23	20.50
7-2	16	12,750	9,410	0.7	24	24.60
8-5	13	12,308	9,770	1	8	26.82
9-3	5	10,616	8,470	53	138	20.85
10-1	17	10,864	8,856	3	5	21.50
PWD-12E						
5-13	6*	8,023	6,310	1	7	9.96
6-4	24	8,621	6,532	0.4	9	8.00
7-2	25	8,500	6,648	0.3	6	9.50
8-5	13	8,276	6,622	1	6	9.59
9-3	9	8,078	7,207	1	4	9.50
10-1	6	9,657	7,175	2	7	9.42
PWD-13E+						
5-13	0	3,597	2,507	180	441	4.97
6-4	0	1,471	922	210	661	1.30
7-2	14	2,429	1,606	115	262	2.98
8-5	2	3,000	2,074	225	836	4.20
9-3	1	1,456	989	385	2	1.92
10-1	2	2,086	1,460	2,400	7,480	2.62

*Flow for one week only.

+Flows are captured water for the tile-drained field.

Appendix Table 25:

Water Sample Locations and Description in
Los Banos Wildlife Area
Mendota-Crows Landing Return Flow Group
1975

No.	Sample I.D.	Sample Description
1	LBWA- 1	San Luis Federal Drain at Henry Miller Ave. water sample upstream from bridge.
2	LBWA- 2	San Luis Canal at Henry Miller Ave. water sample above the check structure.
3	LBWA- 3	Sewage slough at Henry Miller Ave. water sample from north side (downstream) of the road.
4	LBWA- 4	Mud Slough inlet to the area just north of Henry Miller Ave. water sample from the downstream end of culvert.
5	LBWA- 5	Boundary drain inlet water sample at the flume.
6	LBWA- 6	San Pedro Canal water sample from the flume.
7	LBWA- 7	Low Lift #2 (water is same as boundary drain, therefore no sample) only quantity measurement.
8	LBWA- 8	West Delta Canal inlet water sample at the recorder station.
9	LBWA- 9	Outflow to Mud Slough from Buttonwillow Lake water sample from lower end of pipes.
10	LBWA-10	Mud Slough at City drain water sample from the check structure (upstream).
11	LBWA-11	San Luis Canal at Ruth Lake Low Lift (water is same as #2) only quantity measurement.
12	LBWA-12	Water sample from the lower Ruth Lake just southeast of Low Lift.
13	LBWA-13	Water sample from field 11 below gooseneck.
14	LBWA-14	Field #37, 38 discharge into Mud Slough.

Appendix Table 26:

WATER FLOW AND DETAILED WATER QUALITY ANALYSIS, LOS BANOS WILDLIFE AREA

MENDOTA-CROWS LANDING RETURN FLOW GROUP
April 1975 - October 1975

Date	Monthly flow (ac-ft)	EC (µmhos/cm)	TDS (mg/l)	Turbidity (JTU)	SS (mg/l)	B (mg/l)	Na	Ca	Mg	HCO$_3$	Cl	SO$_4$	Total N	Organic N	NH$_4$-N	NO$_3$-N	NO$_2$-N	BOD	DO
							←		meq/l			→	←			mg/l			→
LBWA-1																			
5-1	-	5,667	4,570	12	14	8.83	-	-	-	-	-	-	0.955	0.92	0.03	0.004	0.001	2.40	9.80
6-5	-	7,877	5,632	5	23	11.00	57.00	15.00	16.50	3.65	29.77	56.00	0.903	0.82	0.08	0.002	0.001	1.20	-
7-2	-	8,947	6,973	5	17	15.80	-	-	-	-	-	-	0.908	0.73	0.17	0.008	0.003	2.40	9.10
8-6	-	6,172	4,594	6	10	11.56	42.00	12.50	14.00	2.97	23.30	43.75	1.314	1.25	0.05	0.013	0.001	1.80	7.20
9-4	-	3,963	2,816	5	16	5.42	26.00	8.50	7.50	2.30	12.56	27.00	1.025	0.92	0.08	0.024	0.001	0.60	8.50
10-2	-	3,290	2,374	8	15	4.20	-	-	-	-	-	-	-	-	1.50	0.044	0.002	2.40	9.43
LBWA-2																			
5-1	-	2,833	1,897	58	123	4.40	-	-	-	-	-	-	2.136	1.14	0.06	0.840	0.095	3.00	9.20
6-5	205	2,718	1,719	96	315	4.10	16.75	6.50	3.30	2.40	8.76	14.50	1.862	1.08	0.02	0.680	0.082	0.60	-
7-2	239	2,727	1,824	73	146	4.77	-	-	-	-	-	-	9.908	1.70	0.30	7.780	0.128	1.80	7.60
8-6	0	2,495	1,637	82	134	4.27	14.12	7.00	4.10	2.97	8.37	13.00	5.852	0.15	0.95	4.700	0.052	0.60	6.70
9-4	199	2,068	1,425	63	110	3.45	10.85	7.00	4.06	3.76	7.86	10.25	-	-	2.54	3.100	0.026	6.00	-
10-2	778	718	434	76	197	0.40	-	-	-	-	-	-	-	-	0.05	0.975	0.013	0.60	9.43
LBWA-3																			
5-1	-	2,267	1,441	6	9	1.99	-	-	-	-	-	-	6.520	3.39	2.46	0.160	0.510	12.00	2.75
6-5	-	2,861	1,886	2.5	27	2.78	15.75	7.50	6.70	6.68	10.50	13.00	4.421	4.28	0.12	0.014	0.007	1.80	-
7-2	-	2,318	1,391	4	11	2.08	-	-	-	-	-	-	8.562	2.80	5.70	0.540	0.008	1.20	1.50
8-6	-	2,621	1,672	8	6	3.00	13.75	6.75	7.30	8.45	9.92	10.00	9.917	3.75	6.15	0.011	0.006	4.20	1.40
9-4	-	2,350	1,562	9	9	2.40	12.65	6.50	6.00	8.35	10.28	7.15	7.236	7.03	0.07	0.108	0.028	5.40	-
10-2	-	2,267	1,487	9	3	1.98	-	-	-	-	-	-	-	-	5.00	0.026	0.009	3.00	9.29
LBWA-4																			
5-1	-	3,400	2,229	24	53	4.34	-	-	-	-	-	-	1.611	1.43	0.02	0.160	0.001	10.20	10.60
6-5	-	2,718	1,676	110	357	4.25	6.90	2.60	9.00	3.03	8.98	6.20	2.290	0.00	2.28	0.006	0.002	0.60	-
7-2	-	1,759	1,056	75	128	2.05	-	-	-	-	-	-	1.650	1.15	0.35	0.016	0.000	0.60	6.10
8-6	-	1,543	874	92	152	1.54	9.25	3.30	2.90	2.45	6.68	6.40	3.926	3.19	0.71	0.026	0.000	9.00	5.50
9-4	-	760	467	88	136	0.35	3.60	2.20	2.10	2.71	3.30	1.62	1.924	1.60	0.30	0.024	0.000	3.00	-
10-2	-	879	514	47	67	0.28	-	-	-	-	-	-	-	-	0.03	0.017	0.001	3.60	9.14
LBWA-5																			
5-1	-	1,275	711	32	80	0.54	-	-	-	-	-	-	1.450	0.92	0.03	0.480	0.020	6.00	10.30
6-5	-	1,182	653	41	155	0.08	5.43	2.90	2.00	2.40	5.23	2.60	1.614	1.46	0.04	0.068	0.046	0.60	-
7-2	2,666	1,133	638	47	124	0.28	-	-	-	-	-	-	3.748	2.21	0.29	1.160	0.088	0.60	8.40
8-6	3,844	1,193	617	65	135	0.24	5.43	2.70	2.10	2.45	5.27	2.80	2.912	2.06	0.04	0.740	0.072	0.60	-
9-4	3,900	1,066	638	61	153	0.40	5.18	3.00	2.25	2.71	5.32	2.20	2.190	1.34	0.06	0.720	0.070	3.00	-
10-2	5,456	823	471	46	97	0.16	-	-	-	-	-	-	-	-	0.09	1.055	0.041	2.14	9.14
LBWA-6																			
5-1	685	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6-5	795	755	704	76	274	0.00	3.80	2.00	1.40	2.14	2.95	1.85	2.010	1.13	0.07	0.006	0.004	0.60	-
7-2	599	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8-6	516	682	402	58	68	0.20	3.60	1.90	1.30	2.35	2.85	1.98	1.254	0.83	0.17	0.240	0.014	4.20	-
9-4	534	616	364	95	224	0.23	2.90	1.60	1.50	2.19	2.56	1.10	1.174	1.10	0.10	0.540	0.014	6.60	-
10-2	379	510	311	77	144	0.07	-	-	-	-	-	-	-	-	0.03	0.660	0.013	0.60	9.76

Appendix Table 26: Continued

Date	Monthly flow (ac-ft)	EC (umhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	B (mg/ℓ)	Na (meq/l)	Ca (meq/l)	Mg (meq/l)	HCO_3 (meq/l)	Cl (meq/l)	SO_4 (meq/l)	Total N (mg/l)	Organic N (mg/l)	NH_4-N (mg/l)	NO_3-N (mg/l)	NO_2-N (mg/l)	BOD (mg/l)	DO (mg/l)
LBWA-8																			
5-1	-	981	539	23	57	0.30	-	-	-	-	-	-	1.114	1.01	0.04	0.050	0.014	4.80	-
6-5	160	1,156	631	37	132	0.08	5.18	2.90	2.00	2.45	5.12	2.70	1.494	1.25	0.15	0.054	0.040	0.60	-
7-2	235	1,133	639	34	83	0.42	-	-	-	-	-	-	5.440	2.54	0.36	2.360	0.180	4.20	11.00
8-6	317	959	588	45	83	0.29	5.17	2.38	2.18	2.19	4.85	2.60	2.069	0.58	0.72	0.700	0.069	1.20	-
9-4	417	623	379	37	58	0.23	3.00	1.60	1.80	2.30	2.62	1.30	1.170	0.24	0.26	0.650	0.020	0.60	-
10-2	494	392	240	56	103	0.08	-	-	-	-	-	-	-	-	0.07	0.750	0.009	1.20	9.29
LBWA-9																			
6-5	-	1,394	721	32	78	0.20	7.00	3.00	2.40	2.92	5.77	3.20	2.704	2.59	0.11	0.002	0.002	3.00	-
LBWA-10																			
5-1	-	1,325	755	36	93	0.63	-	-	-	-	-	-	1.510	0.94	0.006	0.500	0.010	4.80	10.20
6-5	-	1,208	702	28	108	0.30	6.10	3.10	2.30	2.40	5.37	3.50	1.518	1.37	0.03	0.072	0.046	0.60	-
7-2	-	1,275	701	48	122	0.51	-	-	-	-	-	-	3.952	1.58	0.07	1.200	0.102	4.20	8.40
8-6	-	1,126	781	65	140	0.30	5.65	3.25	2.50	2.71	5.41	2.80	2.696	1.78	0.02	0.820	0.076	3.00	-
9-3	-	1,149	688	72	215	0.42	5.43	2.75	3.75	2.71	5.61	3.00	1.741	0.81	0.09	0.760	0.081	3.00	-
10-2	-	879	503	53	125	0.21	-	-	-	-	-	-	-	-	0.09	1.090	0.041	4.20	9.29
LBWA-11																			
5-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6-5	80	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7-2	163	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8-6	3.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9-3	414	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
10-2	331	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
LBWA-12																			
5-1	-	2,684	1,644	30	51	2.04	-	-	-	-	-	-	1.611	1.56	0.04	0.010	0.001	8.40	10.20
6-5	-	2,718	1,607	37	87	1.82	9.90	4.00	5.00	3.86	11.35	4.50	3.603	3.53	0.07	0.002	0.001	1.80	-
7-2	-	1,962	1,141	34	75	1.21	-	-	-	-	-	-	2.662	2.59	0.06	0.012	0.000	6.00	8.20
8-6	-	1,576	928	18	29	1.03	9.50	3.50	2.75	3.16	7.53	5.20	1.800	1.77	0.03	0.000	0.000	6.00	-
9-4	-	1,149	688	22	40	0.50	5.88	3.00	3.75	3.13	5.83	3.50	2.130	2.02	0.08	0.024	0.006	1.80	-
10-2	-	1,159	683	39	70	0.42	-	-	-	-	-	-	-	-	0.09	0.240	0.020	4.80	9.29
LBWA-13																			
5-1	-	4,636	3,319	18	54	4.24	-	-	-	-	-	-	2.612	2.57	0.03	0.010	0.002	12.60	11.80
6-5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7-2	-	3,091	1,862	18	46	2.79	-	-	-	-	-	-	2.999	2.76	0.19	0.044	0.000	9.00	11.40
8-6	-	2,248	1,322	27	28	1.98	15.25	3.25	4.00	2.45	10.91	8.58	3.426	3.39	0.01	0.016	0.000	12.60	-
9-4	-	1,543	927	34	73	0.90	9.25	2.50	4.50	2.71	7.97	4.58	3.732	3.65	0.05	0.032	0.000	9.60	-
10-2	-	1,397	813	44	85	70.00	-	-	-	-	-	-	-	-	0.04	0.015	0.001	9.60	9.29
LBWA-14																			
5-1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6-5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7-2	-	1,599	882	17	48	0.57	-	-	-	-	-	-	3.228	2.90	0.30	0.024	0.004	7.20	-
8-6	-	1,527	891	24	43	0.66	9.00	3.75	2.75	3.23	7.81	4.55	2.003	1.98	0.02	0.003	0.000	4.80	13.00
10-2	-	2,318	1,519	7	10	3.00	-	-	-	-	-	-	-	-	0.07	0.009	0.001	3.00	9.43

Appendix Table 27:

Irrigated Crop and Refuge Acreage in the
Glenn-Colusa Irrigation District in 1975

Crop	Acres
Rice	93,326
Tomatoes	1,005
Sugar Beets	1,633
Clover	5,646
Alfalfa	1,845
Corn	1,944
Orchard	1,797
General	6,293
Duck Pond	2,392
One Irrigation	8,281
Second Irrigation	2,124
Subtotal	126,286
Refuge	**Acres**
Rice	750
General	2,300
Duck Pond	3,100
Subtotal	6,150
GRAND TOTAL	132,436

Appendix Table 28:

MONTHLY DRAIN OUTFLOWS 1975

(acre-feet)

Location	April	May	June	July	Aug.	Sept.	Oct.	Total
D1 Salmon Hole	190	1,040	240	830	940	530	230	4,000
D2 Bondurant	760	1,250	1,790	720	200	190	390	5,300
D3 Drain 55	2,190	7,190	8,600	9,080	10,280	9,350	3,510	50,200
D4 Logan Creek	130	2,620	100	590	1,310	2,220	2,830	9,800
D5 2047	1,240	3,960	5,000	4,490	5,050	4,290	970	25,000
D6 Willow Creek	610	4,630	2,430	3,750	4,400	3,960	2,020	21,800
D7 Hunter Creek	1,080	2,110	720	2,690	4,020	5,710	970	17,300
D8 Stone Corral	1,820	2,420	1,940	3,070	3,360	4,410	380	17,400
D9 Kuhl	850	1,240	520	2,000	3,850	4,580	360	13,400
D10 Section 25	720	2,340	990	2,010	3,570	2,740	530	12,900
D11 Freshwater	450	2,930	1,710	4,070	4,670	3,440	430	17,700
Total Measured	10,040	31,730	24,040	33,300	41,650	41,420	12,620	194,800
Estimated District Total	12,500	39,700	30,000	41,600	52,100	51,800	15,800	243,500

Appendix Table 29:

Water Flow and Quality Data for Stations in
Colusa Basin Study Area
April 1975 Through October 1975

Date	Monthly flow (ac-ft)	EC (umhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)
Supply Station for Glenn-Colusa Irrigation District:					
GCID Main Canal, D-14					
4-7	91,700	249	149	53	33
5-5	170,200	325	177	15	28
6-2	166,100	115	80	10	35
7-7	166,100	141	94	10	17
8-4	156,100	121	89	9	7
9-8	62,500	119	130	7	8
10-6	22,700	143	111	7	7
Lateral Drains in Glenn-Colusa Irrigation District:					
GCID 2047 at Sidds Road, D-5					
4-7	1,240	316	184	82	94
5-5	3,960	311	177	17	21
6-2	5,000	316	192	14	52
7-7	4,490	293	181	9	27
8-4	5,050	325	191	13	23
9-8	4,290	303	174	10	14
10-6	970	421	265	14	24
GCID Bondurant, D-2					
4-7	760	299	235	77	117
5-5	1,250	336	197	12	18
6-2	1,790	352	213	10	41
7-7	720	329	140	5	13
8-4	200	372	199	9	9
9-8	190	385	235	6	5
10-6	390	298	194	7	1
GCID Drain 55, D-3					
4-7	2,190	524	226	3	2
5-5	7,190	412	171	13	15
6-2	8,600	290	176	7	34
7-7	9,080	288	168	8	17
8-4	10,280	291	186	10	12
9-8	9,350	270	158	7	9
10-6	3,510	336	212	7	8

Appendix Table 29: Continued

Date	Monthly flow (ac-ft)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)
GCID Willow Creek, D-6					
4-7	610	458	251	38	49
5-5	4,630	344	197	24	33
6-2	2,430	307	181	30	79
7-7	3,750	285	166	13	30
8-4	4,400	300	177	12	18
9-8	3,960	305	182	17	22
10-6	2,020	378	237	22	35
GCID Salmon Hole, D-1					
4-7	190	677	404	23	33
5-5	1,040	412	171	13	15
6-2	240	458	315	17	53
7-7	830	371	214	3	10
8-4	940	402	239	9	9
9-8	530	391	233	11	18
10-6	230	466	299	19	32
GCID Logan Creek, D-4					
4-7	130	1,103	603	64	99
5-5	2,620	647	400	18	21
6-2	100	677	405	19	46
7-7	390	526	329	22	46
8-4	1,310	567	336	14	17
9-8	2,220	595	371	29	34
10-6	2,830	579	366	18	30
GCID Hunter Creek, D-7					
4-7	1,080	402	223	74	121
5-5	2,110	344	205	36	38
6-2	720	408	245	39	79
7-7	2,690	324	186	16	38
8-4	4,020	342	203	9	7
9-8	5,710	345	201	27	44
10-6	970	599	369	41	78

Appendix Table 29: Continued

Date	Monthly flow (ac-ft)	EC (umhos/cm)	TDS (mg/l)	Turbidity (JTU)	SS (mg/l)
GCID Stone Corral, D-8					
4-7	1,830	492	282	77	120
5-5	2,420	494	294	40	31
6-2	1,940	516	296	85	190
7-7	3,070	415	241	22	44
8-4	3,360	436	249	21	34
9-8	4,410	392	234	26	48
10-6	380	984	615	44	75
GCID Hull Weir, D-9					
4-7	850	384	224	79	106
5-5	1,240	391	230	25	26
6-2	320	407	246	17	43
7-7	2,000	329	191	9	30
8-4	3,850	340	200	9	7
9-8	4,380	328	192	14	18
10-6	360	522	336	19	30
GCID Section 23, D-10					
4-7	730	475	263	62	106
5-5	2,340	638	363	24	33
6-2	990	483	292	33	91
7-7	2,010	357	210	13	25
8-4	3,370	358	213	13	17
9-8	2,740	333	190	17	27
10-6	530	984	615	44	75
GCID Freshwater Creek, D-11					
4-7	630	900	526	60	111
5-5	2,930	916	536	19	33
6-2	1,710	790	455	50	93
7-7	4,070	590	339	22	43
8-4	4,670	607	366	21	38
9-8	3,440	538	314	52	97
10-6	430	966	603	52	108

Appendix Table 30

Detailed Water Quality Analysis for GCID Supply Water and Eleven Lateral Drains in Colusa Basin Study Area*

1975 Irrigation Season

Date	EC (µmhos/cm)	Na	Ca	Mg	K	HCO_3	Cl	SO_4	Total N	Organic N	NH_4-N	NO_3-N	NO_2-N	BOD
		meq/ℓ							mg/ℓ					
Supply Station for Glenn-Colusa Irrigation District														
GCID Main Canal, D-14														
6-2	115	0.22	0.50	0.40	0.03	0.99	0.07	0.08	0.92	0.87	0.03	0.014	0.003	3.0
9-8	119	--	--	--	--	--	--	--	--	--	--	--	--	--
Lateral Drains in Glenn-Colusa Irrigation District														
GCID 2047 at Sidds Road, D-5														
6-2	316	0.50	1.38	1.28	0.05	2.61	0.15	0.30	1.05	0.90	0.10	0.032	0.020	2.4
9-8	303	--	--	--	--	--	--	--	--	--	--	--	--	--
GCID Bondurant, D-2														
6-2	352	0.61	1.90	1.65	0.04	3.24	0.15	0.35	0.76	0.64	0.06	0.046	0.012	3.0
9-8	385	--	--	--	--	--	--	--	--	--	--	--	--	--

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*Flow, TDS, turbidity and SS are given in Appendix Table 29 for the corresponding Stations.

Appendix Table 30 (continued)

Date	EC (μmhos/cm)	Na	Ca	Mg	K	HCO_3	Cl	SO_4	Total N	Organic N	NH_4-N	NO_3-N	NO_2-N	BOD
		meq/ℓ							mg/ℓ					
GCID Drain 55, D-3														
6-2	290	0.45	1.28	1.20	0.13	2.61	0.13	0.30	0.52	0.44	0.06	0.006	0.016	3.0
9-8	270	--	--	--	--	--	--	--	--	--	--	--	--	--
GCID Willow Creek, D-6														
6-2	307	0.70	1.18	1.15	0.09	2.66	0.13	0.35	0.95	0.83	0.07	0.032	0.014	3.0
9-8	305	0.70	1.18	1.68	0.07	3.03	0.23	0.24	2.63	0.89	0.06	1.68	0.003	1.2
GCID Salmon Hole, D-1														
6-2	458	1.80	1.50	1.85	0.07	4.02	0.29	0.86	0.85	0.69	0.11	0.040	0.014	2.4
9-8	391	1.31	1.30	2.15	0.07	3.76	0.23	0.40	1.08	0.91	0.04	0.100	0.033	1.8
GCID Logan Creek, D-4														
6-2	677	3.60	1.70	1.80	0.06	3.97	0.63	2.05	1.14	1.03	0.07	0.038	0.002	6.6
9-8	595	3.15	1.00	1.83	0.10	4.41	0.38	1.45	1.43	1.33	0.07	0.028	0.002	1.2
GCID Hunter Creek, D-7														
6-2	408	2.10	1.30	1.05	0.10	2.61	0.52	0.88	1.24	1.04	0.06	0.014	0.010	3.6
9-8	345	1.41	0.35	1.01	0.09	2.19	0.80	0.40	1.41	1.26	0.04	0.112	0.001	0.6

Appendix Table 30 (continued)

Date	EC (µmhos/cm)	Na	Ca	Mg	K	HCO_3	Cl	SO_4	Total N	Organic N	NH_4-N	NO_3-N	NO_2-N	BOD
		meq/ℓ							mg/ℓ					
GCID Stone Coral, D-8														
6-2	516	2.90	1.30	1.05	0.08	2.77	0.83	1.30	1.33	1.19	0.11	0.014	0.02	3.6
9-8	392	1.55	0.40	0.75	0.08	1.57	0.58	0.54	1.29	1.16	0.04	0.092	0.003	0.6
GCID Kuhl Weir, D-9														
6-2	407	2.15	1.20	1.15	0.09	2.77	0.46	0.88	1.43	1.29	0.11	0.010	0.018	4.2
9-8	328	1.45	1.08	1.28	0.08	2.82	0.35	0.44	1.30	1.16	0.04	0.10	0.003	1.8
GCID Section 25, D-10														
6-2	483	2.95	1.05	1.05	0.10	2.77	0.60	0.65	1.52	1.41	0.09	0.012	0.010	4.2
9-8	333	1.60	0.95	1.28	0.08	2.77	0.37	0.44	0.90	0.81	0.04	0.048	0.001	1.2
GCID Freshwater Creek, D-11														
6-2	790	4.60	1.70	1.60	0.11	3.13	1.49	3.00	1.65	1.51	0.09	0.026	0.022	4.2
9-8	538	2.88	1.35	1.65	0.10	3.45	0.85	1.33	2.35	1.12	0.03	1.20	0.003	0.6

Appendix Table 31:

Rice Test Fields - General Information

Glenn-Colusa Irrigation District

1975 Season

Characteristic	Field Number 4	 8	 14	 15
SITE:	Willows	Willows	Willows	Williams
Acres	139	141	153	61
SEEPAGE WATER SAMPLING:				
Inflow	no	yes	no	yes
Middle	yes	yes	yes	yes
Outflow	yes	yes	yes	yes
FERTILIZER:				
Form (rate-lbs/acre)	18(N) - 46(P) - (100)	$(NH_4)_2SO_4$ - (100)	Urea - (121.31)	$(NH_4)_2SO_4$ - (40)
Form (rate-lbs/acre)	N-aqua - (110)		16(N) - 48(P) - (24)	N-aqua - (60)
When applied	4/18	4/24	4/11 to 4/12	4/29
How applied	18-46:airplane	airplane	airplane	$(NH_4)_2SO_4$:airplane
How applied	N-aqua:aqua-rig			N-aqua:aqua-rig
Incorporate	yes	yes	urea only	N-aqua only
TOP-DRESSING:				
Part of program	no	no	no	yes
When applied				7/17
Fertilizer applied				$(NH_4)_2SO_4$
Rate - lbs/acre				31
FLOODING:				
Start - finish	4/18 to 4/21	4/25 to 5/5	4/14 to 4/15	5/4 to 5/11
Inflow device	Hersey-Sparling meter	Hersey-Sparling meter	Hersey-Sparling meter	Hersey-Sparling meter
Outflow device	V-notch weir	V-notch weir	V-notch weir	Parshall flume

Appendix Table 31 (continued)

	Field Number			
Characteristic	4	8	14	15
RICE:				
Variety	Colusa (1600)	CS-M3	CS-M3	Colusa (1600)
lbs/acre	150	170	180	160
Planting date	4/27	5/2 to 5/5	4/15	5/12
HERBICIDE:				
When applied	6/15	6/25	5/13	5/27
Type	MCPA	MCPA	Ordram	Ordram
Rate - gls/acre	.12	.25	.37	--
When applied			6/16	
Type			MCPA	
Rate - gls/acre			.12	
HARVEST:				
Stop inflow water	9/2	9/5	9/2	9/10 to 9/15
Drain field	9/5	9/9	let drain naturally	9/18
Harvest rice	9/22 to 9/30	10/6 to 10/14	10/10 to 10/16	10/15
Yield - lbs/acre	2592	3035	3448	2227

Appendix Table 32:

Rice Test Plot #4, Water Flow and Water Quality Data

Glenn-Colusa Irrigation District

1975 Season

Date	Inflow					Outflow				
	Amount of water* (ac-ft/day)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	Amount of water (ac-ft/day)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)
4-25	9.87	163	107	32	67	1.97	103	88	84	134
5-5	7.86	165	104	17	9	1.07	132	103	30	2
5-15	6.47	150	98	15	31	0.46	146	102	9	15
5-21	5.95	137	104	13	29	0.88	160	118	33	33
6-2	8.06	121	96	14	43	0.00	173	122	22	46
6-20	7.60	159	108	27	122	0.88	111	93	6	8
7-7	7.31	136	93	9	11	1.02	122	88	6	12
7-21	7.81	142	80	13	15	1.20	129	80	17	18
8-4	7.78	145	102	13	25	0.97	144	103	32	75
8-18	7.14	159	91	14	18	1.32	146	103	52	37
9-8	4.21	-	-	-	-	0.52	118	94	115	95

* This flow represents average for the week of the date indicated.

Appendix Table 33:

Rice Test Plot #8, Water Flow and Water Quality Data

Glenn-Colusa Irrigation District

1975 Season

	Inflow					Outflow				
Date	Amount of water* (ac-ft/day)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	Amount of water (ac-ft/day)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)
4-25	13.42	163	108	32	54	-	-	-	-	-
5-5	12.13	160	107	17	4	-	-	-	-	-
5-15	6.42	213	142	3	13	2.82	150	99	17	38
5-21	5.95	146	100	17	44	1.67	192	136	12	17
6-2	5.44	128	85	10	25	0.97	208	130	7	14
6-20	7.87	142	104	77	584	2.27	73	78	2	7
7-7	6.16	137	95	7	2	1.38	98	85	1	10
7-21	5.63	142	80	9	9	0.83	133	90	2	1
8-4	7.17	142	99	12	18	1.10	182	123	3	50
8-18	4.83	146	99	15	22	1.14	196	119	6	2
9-8	3.01	-	-	-	-	2.04	205	128	8	4

* This flow represents average for the week of the date indicated.

Appendix Table 34:

Rice Test Plot #14, Water Flow and Water Quality Data

Glenn-Colusa Irrigation District

1975 Season

	Inflow					Outflow				
Date	Amount of water* (ac-ft/day)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	Amount of water (ac-ft/day)	EC (μmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)
4-25	14.32	163	106	27	41	-	-	-	-	-
5-5	7.91	153	100	16	4	4.15	194	119	42	44
5-15	1.41	150	81	8	10	0.02	268	152	8	16
5-21	1.98	146	108	14	49	3.34	246	165	15	24
6-2	7.47	128	86	14	24	3.07	222	142	5	15
6-20	4.75	134	96	8	9	2.84	176	123	2	7
7-7	9.63	136	93	6	3	3.54	204	136	2	39
7-21	5.73	140	86	8	6	1.68	229	137	2	5
8-4	4.74	144	97	9	5	1.75	249	152	2	1
8-18	3.73	144	97	8	11	2.52	255	140	3	1
9-8	-	-	-	-	-	1.32	244	133	7	4

* This flow represents average for the week of the date indicated.

Appendix Table 35:

Rice Test Plot #15, Water Flow and Water Quality Data

Glenn-Colusa Irrigation District

1975 Season

Date	Inflow					Outflow				
	Amount of water* (ac-ft/day)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	Amount of water (ac-ft/day)	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)
5-15	-	392	242	55	56	1.470	573	320	20	32
5-21	-	336	222	56	81	0.310	727	449	77	93
6-2	-	447	241	33	44	0.330	944	518	7	16
6-20	-	607	328	120	744	0.810	586	347	5	9
7-7	-	345	201	23	2	1.750	466	267	2	106
7-21	-	245	196	16	27	1.590	472	271	2	1
8-4	-	389	227	34	49	1.120	432	258	3	1
8-18	-	340	188	24	36	2.330	425	240	2	2
9-8	-	-	-	-	-	0.006	575	330	32	73

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* No inflow information available due to equipment malfunction.

Appendix Table 36:

Water Flow and Quality Data for Stations Along Colusa Basin Drain in

Colusa Basin Study Area - April 1975 Through October 1975

Date	Monthly flow (ac-ft)	EC (umhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)
Stations on Colusa Basin Drain:					
UCID 2047 at Sidds Road, D-5 is on the main drain, but also serves as a lateral for district.					
CBD-4 at Princeton Road, D-13†					
4-7	1,500	429	244	47	70
5-5	6,138	379	208	23	33
6-2	3,370	360	244	15	71
7-7	9,827	374	226	13	37
8-4	18,445	567	334	19	28
9-8	7,460	347	202	13	28
10-6	2,449	407	263	22	39
CBD-3 at Colusa Bridge, D-12					
4-7	21,193	593	345	78	132
5-5	36,606	633	387	25	43
6-2	27,451	841	481	44	108
7-7	30,922	507	—	23	32
8-4	64,206	567	330	18	37
9-8	60,968	455	269	33	71
10-6	14,349	763	437	63	90
CBD-2 at Davis Weir, D-13†					
4-7	11,906	445	230	160	237
5-5	9,226	715	430	32	34
6-2	71,426	931	524	24	56
7-7	36,902	566	376	27	66
8-4	15,376	606	357	19	39
9-8	71,424	641	371	22	60
10-6	3,690	724	432	25	68
CBD-1 at Road 99E and Road 108					
4-7	7,976	1,273	737	65	74
5-5	23,320	217	140	45	33
6-2	11,350	884	502	67	83
7-7	31,306	730	420	54	98
8-4	37,360	636	389	39	93
9-8	68,390	321	364	113	281
10-7	14,460	802	521	56	76

†represents estimated flow.

Appendix Table 37:

Water Quality Analysis for Station CBD-1
in Colusa Basin Study Area
April 1975 through October 1975

Date	EC (µmhos/cm)	TDS (mg/ℓ)	Turbidity (JTU)	SS (mg/ℓ)	Monthly flow (ac-ft)
4-7	1273	757	45	74	7,976
4-25	859	500	59	79	
5-5	217	140	45	53	25,520
5-15	607	363	33	54	
5-21	585	366	72	107	
6-2	884	501	47	85	11,350
6-12	1064	598	75	114	
6-20	1085	639	100	96	
7-7	720	429	54	99	31,306
7-15	676	414	63	110	
7-21	615	335	69	119	
7-28	653	391	59	92	
8-4	639	389	59	95	57,360
8-11	630	370	57	89	
8-18	607	323	74	129	
8-25	532	323	60	93	
9-2	498	316	83	174	68,590
9-8	521	344	115	281	
9-13	526	327	77	166	
9-23	607	375	78	135	
9-30	689	410	59	86	
10-7	802	521	56	76	14,460
10-13	657	418	43	64	
10-20	810	520	45	70	
10-28	869	537	32	47	

Appendix Table 38:

Detailed Water Quality Analysis for Stations on Colusa Basin Drain in Colusa Basin Study Area*

1975 Irrigation Season

Date	EC (μmhos/cm)	Na	Ca	Mg	K	HCO$_3$	Cl	SO$_4$	Total N	Organic N	NH$_4$-N	NO$_3$-N	NO$_2$-N	BOD
		←			meq/ℓ			→	←		mg/ℓ			→
CBD-5 at Princeton Rd. (D-15)														
6-2	360	1.22	1.70	0.90	0.07	3.18	0.15	0.44	1.05	0.94	0.06	0.032	0.014	3.0
9-8	347	0.83	1.35	2.04	0.06	3.55	0.23	0.24	0.99	0.80	0.05	0.140	0.003	0.6
CBD-3 at Colusa Bridge (D-12)														
6-2	841	4.60	1.80	2.50	0.13	4.28	1.37	2.60	1.83	1.69	0.11	0.014	0.012	4.2
9-8	455	1.80	0.60	1.65	0.06	2.82	0.13	0.82	1.23	1.05	0.05	0.132	0.002	0.6
CBD-2 at Davis Weir (D-13)														
6-2	931	5.30	2.00	2.30	0.16	4.38	1.70	3.20	1.74	1.58	0.12	0.024	0.016	3.6
9-8	641	3.00	1.25	1.85	0.12	4.07	0.76	0.86	1.44	1.36	0.06	0.04	0.001	1.8
CBD-1														
6-2	884	4.80	1.90	2.10	0.14	4.38	1.59	2.86	1.15	0.67	0.43	0.024	0.023	1.2
9-8	521	2.45	1.40	2.05	0.10	4.07	0.73	0.95	1.14	1.06	0.04	0.037	0.008	0.6

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* Flow, TDS, turbidity and SS are given in Appendix Table 36 for the corresponding stations.